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# The SCIENTIFIC MONTHLY

September 1944

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# THE SCIENTIFIC MONTHLY

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IN 1848, on September 20, the Association was formally organized and held its first meeting; in 1874 it was incorporated under the laws of the Commonwealth of Massachusetts and given the right to receive, purchase, hold and convey property. Its governing body is a Council, now having 255 members.

The Association is national in scope, with membership open to the whole world on equal terms, and its interests include the broad fields of the natural and the social sciences. Its varied activities are carried on under 16 sections with which 189 affiliated and associated societies, having a combined membership of nearly a million, cooperate in organizing programs for its meetings.

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names of many university presidents, of eminent scholars in widely different fields, and of men notable for public service, including a United States Senator, a Justice of the Supreme Court, and a former president of the United States, are now on its roll of more than 25,000 members.

The Association's meetings are field days of science attended by thousands of participants at which hundreds of scientists vie with one another for the pleasure and the honor of presenting results of researches of the greatest benefit to their fellow men. An enlightened daily press reports their proceedings throughout the country.

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A world torn by conflicts and fearful of the future is looking more and more toward scientists for leadership. The opportunity for unparalleled service is theirs and the fact that they have available the only essentially new methods, if not purposes, imposes an equal responsibility. For these reasons it will be the Association's steadfast purpose to promote closer relations among the natural and the social scientists, and between all scientists and other persons with similar aspirations, to the end that they together may discover means of attaining an orderliness in human relations comparable to that which they find in the natural world about them.

## MEET THE AUTHORS

ZWORYKIN and HILLIER: see p. 179 in this issue.



E. WILLARD MILLER, Ph.D., is Assistant Professor of Geology and Geography at Western Reserve University, Cleveland, Ohio. He was born in Turkey City, Pa., in 1915 and graduated from the Clarion State Teachers College, Pennsylvania, where his interest in geography developed.

Continuing his study of geography and geology, he took his master's degree at the University of Nebraska in 1939 and his doctor's degree at The Ohio State University in 1942. Dr. Miller has been particularly interested in the study of petroleum regions, on which subject he has published many articles, for example, "The Role of Petroleum in the Middle East" in the September, 1943, issue of THE SCIENTIFIC MONTHLY.



PIERRE DANSEREAU, B.A., B.S.Agr., D.Sc., has been Assistant Director of Technical Services at the Montreal Botanical Garden since 1940. He is connected with the Université de Montréal and his letterhead bears the address: Service de Biogéographie, Université de Montréal, 2900

Boulevard du Mont-Royal, Montreal, Canada. He was born in Montreal in 1911, took his B.A. from Université de Montréal in 1931, his agricultural degree from Institut Agricole d'Oka in 1936, and his doctor's degree from Université de Genève in 1939. He has traveled throughout Canada and Europe and is familiar with parts of the United States. In his travels he collected materials for botanical studies. His study of cytogenetics, plant taxonomy, and ecology in France, Switzerland, and England prepared him to found the Service de Biogéographie, which proposes to teach plant and animal ecology as one subject. Through its research on the interaction of natural forces, it hopes to lead to more permanent solutions of problems concerning the protection of biological resources in Quebec.



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## NEW BOOKS\*

**Elements of Bacterial Cytology.** GEORGES KNAYSIL. xii + 209 pp. Illus. 1944. \$3.50. Comstock Publishing Company.

If this were a popular book, it might have been called "Inside Bacteria," but it is a monograph presenting the present status of our knowledge of bacterial cells. Included are many electron micrographs of bacteria showing structures that were previously unknown.

**The Navaho Door.** ALEXANDER H. LEIGHTON and DOROTHEA C. LEIGHTON. Illus. xviii + 149 pp. 1944. \$4.00. Harvard University Press.

The Leightons have written a readable report of their sojourn and observations among the Navaho Indians with particular reference to medical practices among them. Direct quotation is frequently used to present information gained from these Indians.

**Speed in Animals.** A. BRAZIER HOWELL. Illus. xii + 270 pp. 1944. \$4.00. University of Chicago Press.

Here is an attractive monograph on a subject that has not heretofore received comprehensive study. The author is concerned not only with the measured speed of vertebrates from fishes to mammals, but with their structural morphology conducive to it.

**Peace, Plenty and Petroleum.** BENJAMIN T. BROOKS. Illus. vi + 197 pp. 1944. \$2.50. Jaques Cattell.

A popular account of a popular subject, this book deals with the past, present, and future of petroleum, with emphasis on the various factors that should affect the availability of petroleum products in this country. Even political questions are discussed.

**Many Happy Days I've Squandered.** ARTHUR LOVERIDGE. Illus. 278 pp. 1944. \$2.75. Harper and Brothers.

To the weary editor the title of this book is fascinating. He would like to read it and squander a few hours himself. The author says his book "consists only of tales of the many happy days of a life through whose warp and woof reptiles and animals are inextricably woven."

**Photomicrography in Theory and Practice.** CHARLES P. SHILLABER. Illus. viii + 773 pp. 1944. \$10.00. John Wiley & Sons, Inc.

Although this is a highly technical book, it is noticed here because of its photographs, which show what can be done to illustrate the details of microscopic objects when the photographer knows his business. Electronic photomicrography is not included.

**Medical Education in the United States before the Civil War.** WILLIAM FREDERICK NORWOOD. xvi + 487 pp. 1944. \$6.00. University of Pennsylvania Press.

This scholarly volume represents the results of arduous studies on the early history of medical education in this country. The history of all the older medical schools is presented, and in the light of this information the evolution of the American system of medical education is traced.

\* Orders for the books noticed above should not be sent to THE SCIENTIFIC MONTHLY or the A.A.A.S., but to your bookseller or the publisher.

## MEET THE AUTHORS, Continued



LEON AUGUSTUS HAUSMAN, Ph.D., is Professor of Zoology in the New Jersey College for Women (affiliated with Rutgers University), New Brunswick, N. J. He was born in New Haven, Conn., in 1888 and took both his undergraduate and graduate work at Cornell in geology and biology.

Dr. Hausman came to Rutgers in 1923 as a protozoologist, though his chief research interest was and is the comparative study of the structure of mammalian hairs. Outside of the laboratory he is most interested in birds and has developed his amateur birding to a professional level, as he has become consulting ornithologist of the New Jersey Experiment Station and lately has published *The Illustrated Encyclopedia of American Birds*. Dr. Hausman spends his summers at Blueberry Hill, Fitzwilliam, New Hampshire, in a genuine colonial cottage. Here he adds to his bird lore and to his knowledge of old New England.



SAMUEL BRODY, Ph.D., is Associate Professor in the Department of Dairy Husbandry at the University of Missouri. He was born in 1890 and lived for fifteen years in a farming village in western Russia. His higher education was obtained at the University of California and the University

of Chicago, from which he took his doctor's degree in 1928. His whole professional career has been spent at the University of Missouri, where he has become well known for his researches on the time relations and mechanisms of the growth of animals, which also involved studies of senescence and production of milk, eggs, meat, and muscular work. As a Guggenheim fellow in 1930-31, Dr. Brody traveled widely in Europe. Now he devotes most of his time to research in his capacity as chairman of an inter-departmental committee on growth, development, and metabolism. He was in charge of the Herman Frasch Foundation Research for Agricultural Chemistry at the University of Missouri.

## MEET THE AUTHORS, Continued



PAUL D. LAMSON, M.D., hopes to become Professor of Biotrepy at the School of Medicine of Vanderbilt University, in Nashville, Tenn. His present title is Professor of Pharmacology in that school. He was born in Charlestown, Mass., in 1884 and naturally became a Harvard man. After taking

his M.D. at Harvard in 1909, he studied abroad in 1911-12. His professional career in pharmacology (biotrepy) began at Johns Hopkins in 1914. Since then he has been active in research on anthelmintics, anesthesia and shock, etc. He has published a book entitled *The Heart Rhythms*. In addition to getting out many publications of his own, he was formerly the Editor-in-Chief of the *Journal of Pharmacology and Experimental Therapeutics*.



JAMES F. BENDER, Ph.D., is the founder of the National Institute for Human Relations at 545 Fifth Avenue, New York City. This Institute offers consulting services to business and industry. Dr. Bender was born in Dayton, Ohio, in 1905 and was educated at Columbia, taking his

Ph.D. in 1939. While working toward his doctor's degree he was an instructor in speech at the College of the City of New York. Since 1937 he has been a professor in Queens College, where he organized the Department of Speech and the Queens Speech and Hearing Service Center. For several years he was adjunct professor of psychology at Brooklyn Polytechnic Institute. Dr. Bender's professional career has been devoted to the improvement of speech. He has conducted speech clinics in various schools, and from 1939-1941 he headed a committee of speech educators in making a survey of the speech handicapped children in the New York City schools. He is the coauthor of three standard texts in speech correction and author of three books. Dr. Bender is associate editor of the *Journal of Speech Disorders* and a member of the editorial board of *Speech Monographs*.

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### MEET THE AUTHORS, Continued



JOHN G. SINCLAIR, Ph.D., is Professor of Histology and Embryology, Medical College, University of Texas, Galveston. In 1888 he was born in Grand Haven, Michigan, where he grew up. He attended the Universities of Illinois and Chicago and received his advanced degrees from the

Universities of North Dakota and Wisconsin. In 1914 he undertook a one man botanical, meteorological and anthropological expedition in Colombia. During World War I he served in the Meteorological Section of the Signal Corps at Aberdeen, Md., and in France. Dr. Sinclair taught in the Universities of Chicago, North Dakota, and Wisconsin and at Beloit College before coming to Texas sixteen years ago. He combines broad scientific interests with artistic talent, which he expresses in genuine poetry. His major research is on experimental modification of the parathyroid gland through diet and pregnancy, but for Dr. Sinclair "life is full of a number of things . . ."



S. J. HOLMES, Ph.D., LL.D., now professor emeritus of Zoology of the University of California at Berkeley, was born at Henry, Illinois, 1868. He graduated at the University of California in 1893 and took his Ph.D. at the University of Chicago in 1897. After having taught at the Universities of Michigan and Wisconsin he was called to his alma mater in 1912. His research activities have been carried on in a number of fields: systematic zoology of the Crustacea, embryology, animal behavior, and eugenics. His later books and articles have been mainly in the two last mentioned fields. The problem of organic form, the subject of the present and two following articles, has long enlisted his interest, although he published little on it since 1904. Professor Holmes is a past president of the American Society of Zoologists, the American Society of Naturalists, the Eugenics Society of America, and the Pacific Division of the American Association for the Advancement of Science.

# THE SCIENTIFIC MONTHLY

SEPTEMBER, 1944

## ELECTRONIC MICROSCOPY

By V. K. ZWORYKIN and JAMES HILLIER

DURING the latter half of the last century Abbe demonstrated the diffraction theory of microscopic vision and in so doing discovered the limitations imposed on the resolving power of any microscope by the wave nature of the radiation used. Mathematically he was able to show that no matter how perfect the lens system of a microscope it cannot produce resolved images of structures which are separated by less than one-half the wave-length of the light used. This naturally led to the use of light of shorter and shorter wave-lengths in the ordinary optical microscope. Finally by the use of ultraviolet light the resolving power of the optical microscope was increased some two and a half times. It was not possible, however, to extend the resolving power indefinitely by this method because of the apparently fundamental lack of suitable lenses for extremely short wave-lengths. The highly perfected optical microscopes of the present have almost attained the theoretical limits indicated by Abbe. Using visible light they can resolve structures separated by 250 millimicrons (0.00001 inch), whereas with ultraviolet light they can resolve as low as 100 millimicrons.

In discussing the limiting resolving power of a microscope it is usual to state it as a "maximum useful magnification." Unfortunately, there has been considerable confusion regarding the use of this term because the magnification of any microscope can be adjusted by the use of proper lenses to any value that the user desires. The term "maximum useful magnification" refers to that magnification at which the finest details resolved by the lens system become just visible to the unaided eye. Thus if we assume that

the human eye cannot resolve less than 0.2 millimeters, we find that it requires a magnification of 800 diameters to make visible to that eye the details resolved by a microscope using visible light. On the same basis the maximum useful magnification which can be obtained with a microscope using ultraviolet light is around 2000 diameters.

For many years the problem of improving the resolving power of the microscope appeared to be incapable of solution. The search, however, had been restricted almost entirely to the realm of optics, whereas actually the solution lay in an entirely different field—electronics.

### THE ELECTRON MICROSCOPE

A little over fifteen years ago it was found that the path of electrons in electric and magnetic fields could be described in terms which are analytically equivalent to those of optics. By means of this electron optical equivalence it was shown that axially symmetric electric or magnetic fields had the properties of optical lenses, and, consequently, that it is possible to form electron images in the same way that light images can be formed. At about the same time the discovery had been made that any material particle in motion had associated with it a characteristic wave-length. For electrons (accelerated by 60 kilovolts) this wave-length was found to be very small—around 0.05 angstrom unit or only about 1/100,000 that of visible light. This meant that suitably designed electronic systems employing these high-speed electrons should be capable of extremely high resolving power.

These two concepts led directly and logically to the idea of an electron microscope

based on principles similar to those used in an optical microscope, but in which the various components are replaced by their electron optical equivalent (Fig. 1). Such an instrument employs condenser, objective, and projection lenses performing the same functions as the corresponding elements in the light microscope, but the lenses, instead of being made of glass, are formed by axially symmetric electric or magnetic fields. During the past ten years, instruments of this type have been investigated in detail in various parts of the world. As a result, the electron microscope has been developed to a point where it is capable of a useful magnification nearly two orders of magnitude greater than the ordinary light microscope. Until recently the development has been in the hands of physicists, and the instruments built were designed almost entirely for the purpose of studying the microscope itself. However, the electron microscope has progressed beyond this stage and has now become a re-

search tool of great value. Ever-growing numbers of commercially built electron microscopes are being put into use in all types of research organizations, and already many important, and even some spectacular, results have been achieved.

All electron microscopes which have been built to give the highest possible resolving power have followed a more or less conventional pattern. They consist of three essential components: the electron microscope proper, the power supply, and the vacuum system. Figure 2 (left) is a photograph of the RCA Type B electron microscope in which all three components are combined into a single unit. Figure 2 (right) is a sectional diagram indicating details of construction more clearly. The electrons used in the imaging process are supplied from the electron gun (A) including a thermionic cathode which is maintained at 60 kilovolts negative with respect to ground and a final anode at ground potential. Between the two are

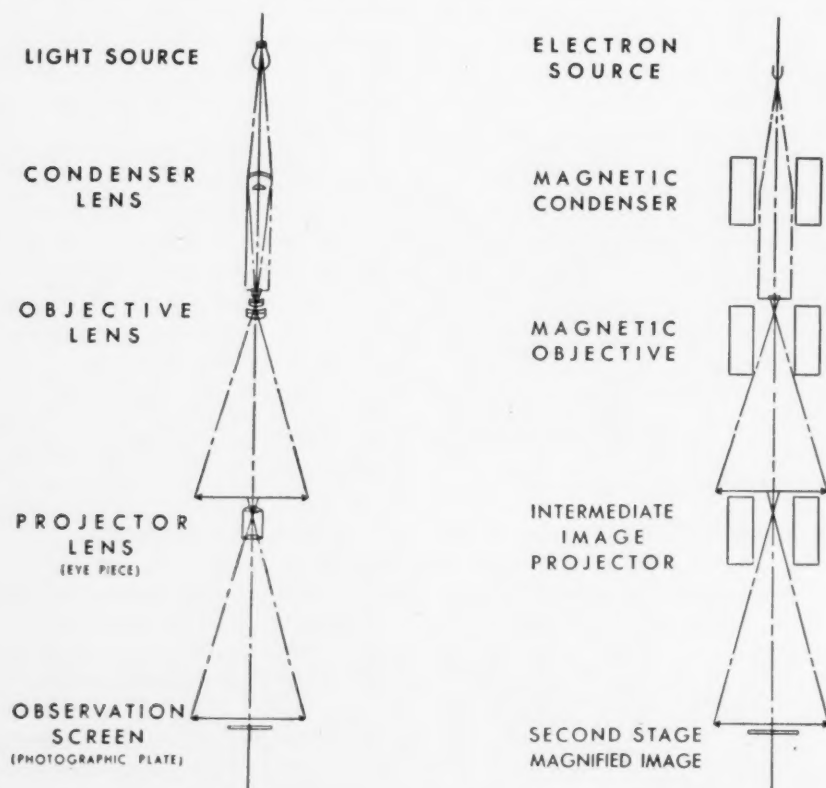


FIG. 1. SIMILARITY BETWEEN A LIGHT MICROSCOPE AND AN ELECTRON MICROSCOPE

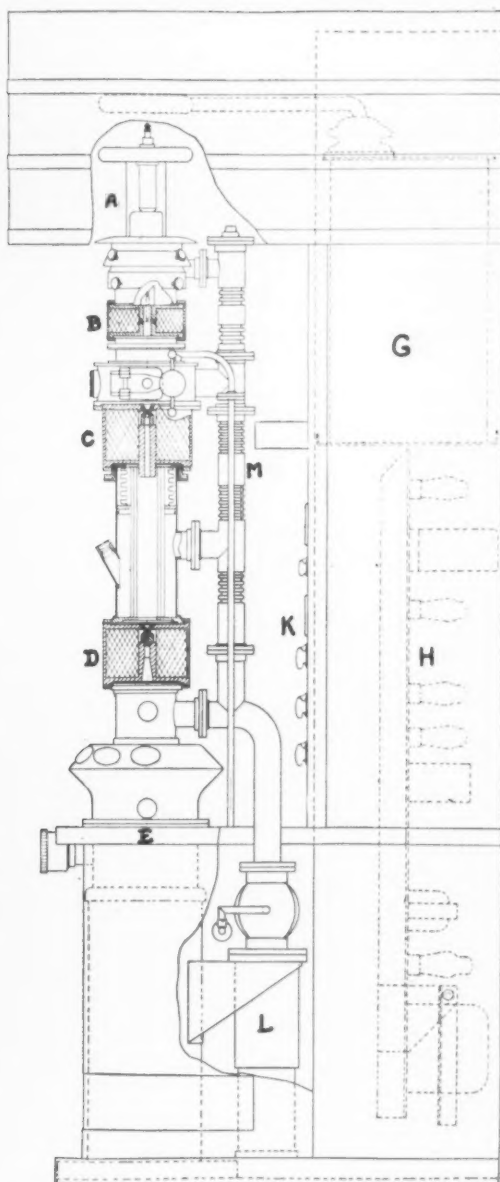
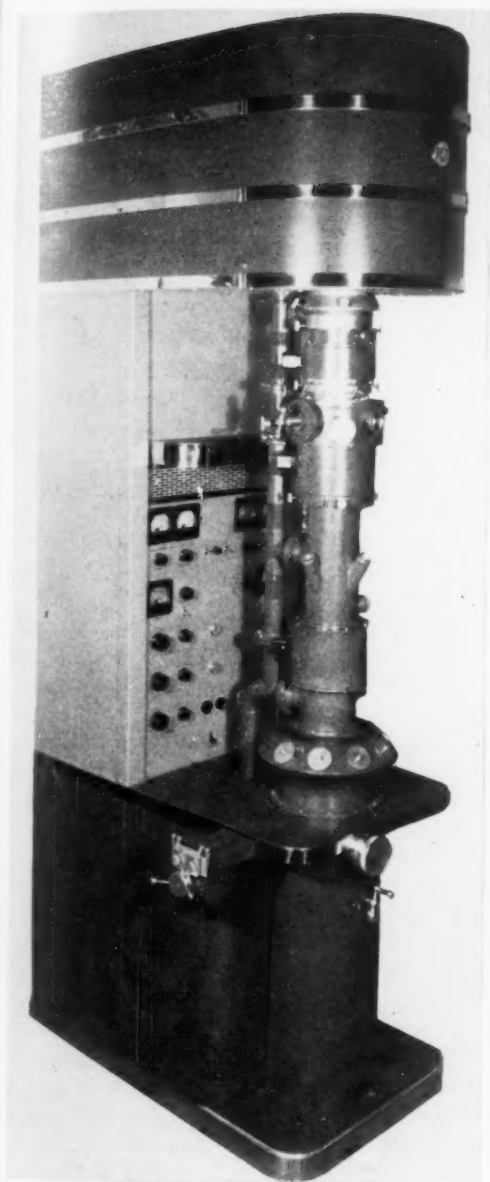


FIG. 2. LEFT, AN RCA ELECTRON MICROSCOPE; RIGHT, CROSS SECTION OF SAME

disposed the electrodes required for controlling the electron paths. The electrons leaving the gun have their full velocity, corresponding to 60 kilovolts.

The condenser lens (B), which consists of an iron-clad coil with polepieces shaped to give the required magnetic field, causes the electrons to converge upon the specimen held a few centimeters below it. The condenser, like the condenser lens of a light microscope,

can be used to control the angular aperture and hence the intensity of the illumination at the specimen.

After passing through the specimen, the electrons enter the objective lens (C). This lens deflects the electrons leaving the specimen in such a way as to focus them into a magnified intermediate image of the specimen. This image is formed directly above the projection lens (D). The objective, like

the condenser, is an iron-clad coil, but the polepieces are, of course, different in design to meet the requirements of this element.

The final image is formed from that portion of the intermediate image which passes through the projection lens (D) and is re-imaged in the plane of the observing screen or photographic plate at (E). The observing screen is coated with a fluorescent material producing a visible image by means of which the operator can focus the instrument and can adjust the specimen to obtain an appropriate field of view. The fluorescent screen is hinged so that it serves as a shutter to the photographic chamber immediately below it. The photographic record is made by allowing the electronic image to fall directly on the sensitive emulsion of the photographic plate.

The magnification of the objective lens is usually around  $100\times$ , though by changing the position of the specimen and the strength of the lens it can be adjusted to lie anywhere between  $50\times$  and  $100\times$ . The magnification produced by the projection lens can be varied from  $20\times$  to  $300\times$  so that the total magnification of the instrument can be controlled over the range  $1000\times$  to  $30,000\times$ . By properly modifying the polepieces of the objective and projection lenses, the instrumental magnification can be varied from as low as  $200\times$  to as high as  $100,000\times$ . However, as mentioned earlier, the magnification used has little significance as a measure of performance of the instrument. This type of electron microscope is capable of a resolving power of as low as 2.0 millimicrons, which corresponds to a maximum useful magnification of around  $10,000\times$ . In practice, however, it is found that *instrumental* magnifications of this magnitude are both unnecessary and undesirable. Instead, magnifications of the order of  $10,000\times$  are used, and the images are recorded on fine grain photographic emulsions which permit subsequent optical magnifications of  $10\times$ . In this way the full useful magnification of the electron microscope can be attained with a minimum exposure, minimum requirements of the power supplies, and maximum field of view.

All the power supplies (G) and (H) and electrical controls (K) necessary for the operation of the electron microscope are contained in the cabinet at the rear of the micro-

scope column. Since the power of a magnetic lens depends on the current through the lens coil and on the velocity of the electrons being focused, it is obvious that sharp photographic records would not be possible if any of these quantities varied during the exposure time. Therefore, it is essential that all the voltages and currents be extremely stable. To accomplish this, special electronically stabilized power supplies were developed in which the lens currents and the high voltage supply are held constant to within 0.005 per cent. To stabilize the high voltage, a sample of the voltage is compared with that of a standard battery. Any slight differences which may occur between the sample and the standard are amplified and used to control and correct the main system. In the case of the coil currents the method is the same except that the voltage drop occurring across a standard resistor through which the coil current is flowing is used as the sample.

Electrons will not travel freely through air; hence the entire electron optical path of the microscope must be under vacuum; that is, at a pressure of about 0.0001 millimeter of mercury. Since an electron microscope is a rather complicated instrument, having a number of parts which must be moved inside the vacuum, and requires facilities for quickly removing and introducing specimens and photographic materials, as well as for ease in disassembling and servicing, a number of innovations in vacuum practice have been introduced. A number of the joints, such as those between the electron lenses and the microscope chambers, are made demountable. Such joints are sealed by means of synthetic rubber gaskets and are arranged in such a way that the alignment is maintained by metal-to-metal contacts rather than by metal-to-plastic contacts. At certain points in the microscope, parts must be movable with respect to one another in order to permit alignment. Such points are joined by flexible metal bellows so the adjustments may be made while the microscope is under vacuum and in operation. If, in an instrument of this size, it were necessary to repump the entire microscope every time a specimen or photographic plate is changed, it would greatly curtail the speed of operation. Consequently, air locks are provided which per-

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mit making these changes without breaking the main vacuum.

The main microscope chamber is pumped through the large manifold (M) by a fast oil diffusion pump (L). This pump is backed by a mechanical forepump. A second mechanical pump is used to exhaust the two air lock chambers.

While the electron optical design of an electron microscope is quite analogous to the optical design of a light microscope and while the images of one object formed in the two instruments are *geometrically* identical, there are fundamental differences in the mechanism of the image formation in the two instruments. They correspond in that the differences in intensity, which constitute the image in either case, are the result of differences in the nature and amount of interaction between the incident beam and the points of the specimen. However, in the case of the light microscope the differences in interaction between various points of the specimen and the illumination are due to differences in index of refraction, in selective absorption, in scattering power for the light used, in the conditions of reflection from variously orientated surfaces, and in the size of smaller particles; whereas in the case of the electron

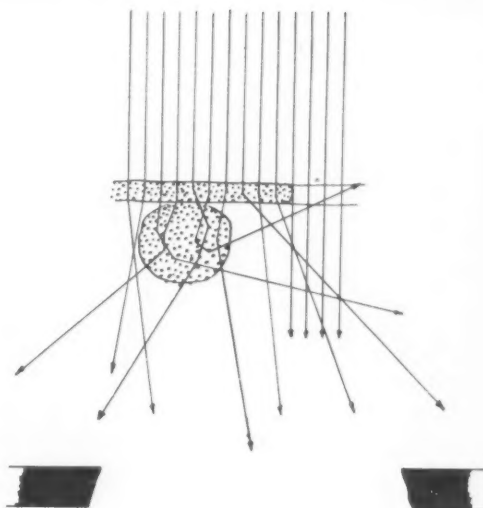


FIG. 4. SCATTERING OF ELECTRONS  
THE THICKER AND DENSER PARTS OF THE SPECIMEN  
DEFLECT ELECTRONS AWAY FROM THE LENS APERTURE.

microscope they are due to differences in the scattering power, in the interference conditions for crystalline particles, and in the size of the particles.

Figure 3 shows diagrammatically the trajectories of the electrons in a fine pencil arriving at the specimen and passing through the objective. It is shown that any point of the specimen is illuminated by a fine beam of electrons, all of which are contained in a cone of extremely narrow half-angle. Of the electrons passing through the specimen, only those whose paths make relatively small angles with the axis of the system will pass through the objective aperture and reach the intermediate image. Thus, the intensity of any point of the image will depend on the number of electrons which left the corresponding point of the object in a direction enabling them to pass through the objective. This will, in turn, depend on the scattering power and hence the mass density of the specimen point. This is illustrated in Figure 4 where the cross section of the specimen has been greatly enlarged and some of the probable electron paths have been drawn in. It can be clearly seen how areas of greater thickness or greater density increase the scattering power of the object and hence decrease the intensity of the corresponding image points.

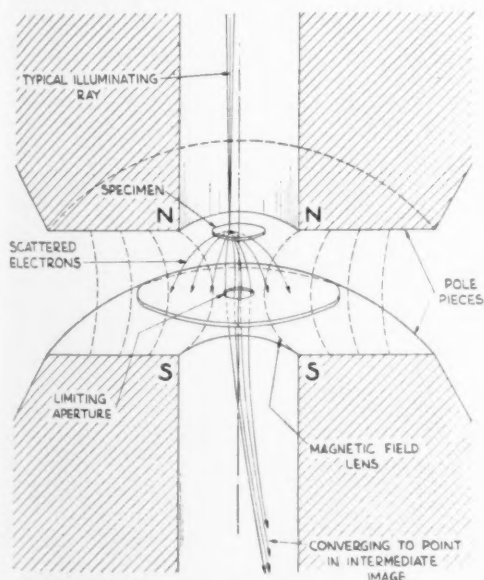


FIG. 3. ELECTROMAGNETIC OBJECTIVE  
THE ELECTRON PATHS ARE REPRESENTED BY SOLID,  
ARROWED LINES; MAGNETIC FIELD LINES ARE DOTTED.

## ASSOCIATED DEVELOPMENTS

The electron microscope by itself provides exact information regarding the size, shape, and structure of finely divided matter, but little more. To make full use of its powers it is necessary to use it in conjunction with other equipment or experiments, some of which can be combined with the instrument itself.

*Stereomicrographs.* An ordinary micrograph, whether obtained with an electron microscope or with a light microscope, represents the object in two dimensions only; in effect, it shows a projection of the object on a plane normal to the instrument axis. The characteristics of the object in the third dimension (in a direction along the axis) can be inferred only indirectly. On the other hand, if the object is viewed from a different angle by each eye, the brain fuses the two images; the result is a perception of the object in its three dimensions. Thus if two micrographs of the same object, inclined by a small angle (e.g.,  $4^\circ$ ) in two opposite directions to the axis of the objective, are viewed in an ordinary stereoscope, a three-dimen-

sional representation is obtained. In the case of high-power light microscopes this procedure is impractical since their depth of focus is so small that the required inclination of the object would blur the image, except in a very narrow range. The electron microscope, on the other hand, has extraordinarily great depth of focus and is ideally adapted for this purpose. To obtain the two stereomicrographs the object screen is inserted at the bottom of the special object holder. It is placed in the object chamber, and a first exposure is made. Then the holder is taken out and the central inclined portion is rotated through  $180^\circ$  about its axis. After the holder, also rotated by  $180^\circ$ , has been reinserted into the object chamber, the second exposure is made; except for a reversal of its inclination with respect to the optic axis, the object occupies now the same position relative to the objective as in the first exposure. The impression of depth in the resulting stereopictures is striking. Figure 5 is a stereomicrograph of zinc oxide smoke.

*Electron diffraction adapter.* Of even greater value, especially for the chemist, is an adapter which converts the electron micro-

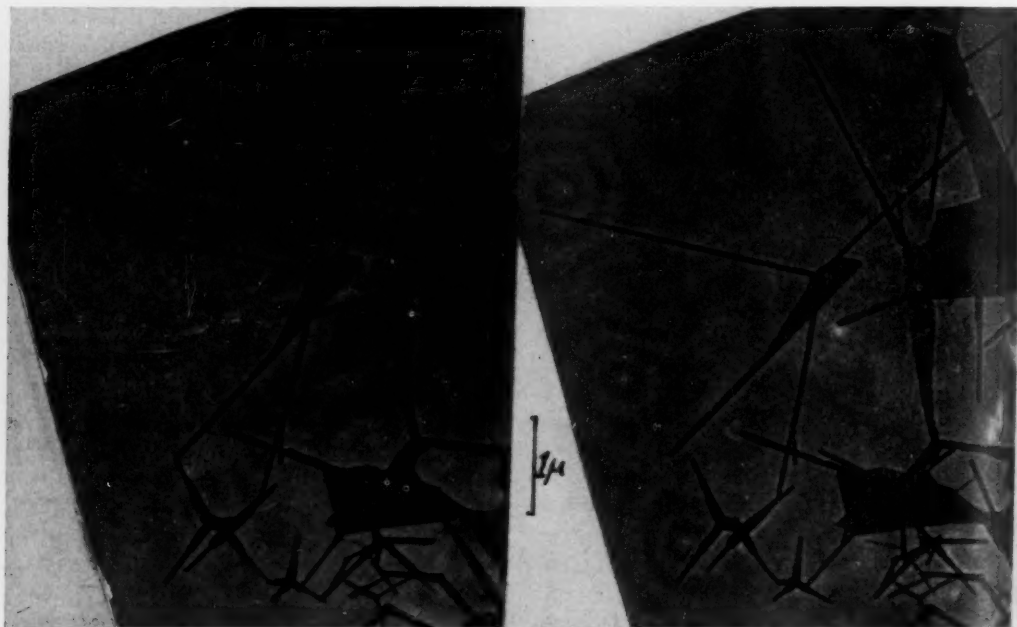


FIG. 5. STEREOSCOPIC ELECTRON MICROGRAPH OF ZINC OXIDE SMOKE  
WITH PERSISTENT PRACTICE THE TWO PHOTOGRAPHS CAN BE VIEWED AS ONE WITHOUT A STEREOSCOPE IF A CARD  
IS HELD BETWEEN THEM SO THAT EACH EYE SEES ONLY ITS RESPECTIVE IMAGE. ENLARGED ABOUT 13,350X.

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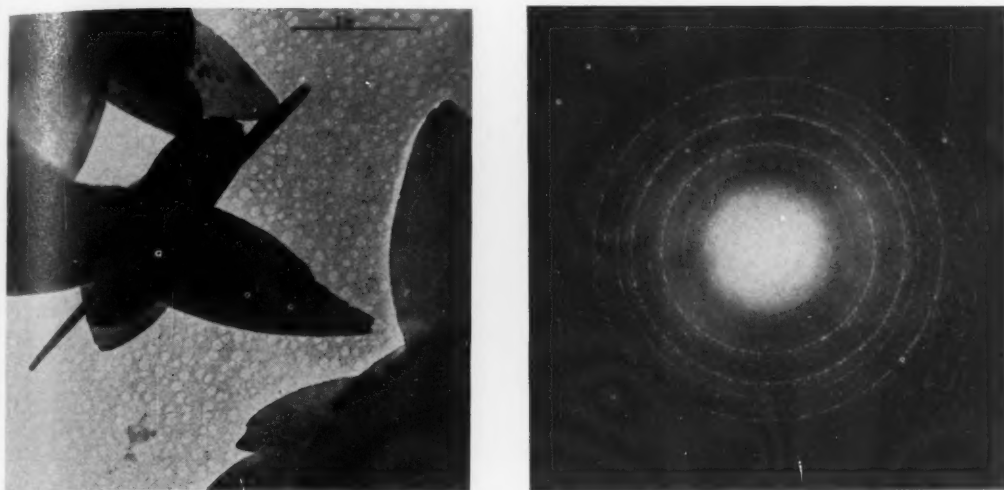


FIG. 6. A CHEMICAL COMPOUND AND ITS DEFLECTION OF ELECTRONS

Left, ELECTRON MICROGRAPH OF MONOHYDRATED ALUMINUM OXIDE; right, ITS ELECTRON DIFFRACTION PATTERN.

scope into a high-precision electron diffraction camera for the determination of the crystalline structures of materials. This adapter replaces the usual projector lens by a unit containing, in addition to a magnetic projector lens, a specimen holder and a special focusing lens for the diffraction camera. When the electron microscope is used as a diffraction camera, the specimen is removed from the object chamber and inserted above the special focusing lens. The objective forms an exceedingly fine point image of the source, so that any part of the specimen is struck by electrons coming from one direction only. The projector lens is rendered inoperative. At the object the incident electrons are deflected or "diffracted" through angles which are characteristic of the relative separations and orientations of the atoms in the crystal lattice of the specimen. The focusing lens serves to concentrate all electrons deflected through a given angle and in a given direction at the same point of the plate.

The specimen holder of the camera is designed for a quick and convenient transfer of a specimen from the microscope object chamber to the camera, so that the diffraction pattern, giving information regarding the crystalline structure of the materials, may be compared directly with the micrograph of the same substance. It is also convenient for the study of any other small specimens,

whether transparent or opaque to electrons; in the latter case it must be so oriented that the electron beam just grazes the surface. Provision is made both for moving the specimen back and forth and for rotating it after it has been introduced into the vacuum.

If the substance studied consists of small crystalline particles oriented in random fashion, the deflection of the ray through a given angle may take place with equal probability in any azimuth, so that the diffraction points on the plate arrange themselves in circular rings about the axis, giving rise to a so-called Debye-Scherrer diagram. The spacings and relative orientation of neighboring atoms in the crystal lattice may be determined from the diameters of the rings. This can be done to within 0.3 per cent. Figure 6 (right) shows the electron diffraction pattern which corresponds to the monohydrated aluminum oxide shown in Figure 6 (left).

*A 300-kilovolt electron microscope.* It has already been mentioned that the scattering and absorption of electrons by matter is such that only very thin specimens can be examined successfully with the standard electron microscope, which has an accelerating voltage of 60 kilovolts. In many fields of investigation this represents no particular limitation. Particularly in the study of very fine structures and dispersed material, where



FIG. 7. AN EXPERIMENTAL SCANNING ELECTRON MICROSCOPE

the thicknesses are comparable to the widths of the individual entities, the substances are adequately transparent. Not infrequently the operation at voltages below 60 kilovolts



FIG. 8. MICROGRAPHED BY SCANNING IMBEDDED IN BAKELITE, PARTICLES OF CARBONYL IRON WERE SCANNED. MAGNIFICATION ABOUT 1,290 X.

presents a definite advantage; greater image contrasts are possible and hence easier recognition of very thin structures. However, in a number of other cases, such as the study of the inner structure of large bacteria and the study of cut sections in histological research, the thickness of the specimen is such that the field appears completely opaque or that interesting structures appear only with inadequate definition. Under such circumstances the use of electrons of greater velocity and hence of greater penetration becomes profitable.

With this in mind, an electron microscope operating with electrons accelerated through potential differences up to 300 kilovolts was constructed. The principal modification of the instrument rests in the high-voltage equipment, which is housed in a large separate oil tank, and in the design of the "electron gun," in which the electrons acquire their high velocity.

With this instrument some of the structures which appear opaque in lower voltage instruments can be examined.

*Scanning electron microscope.* It has already been indicated that electron microscope specimens must be sufficiently thin if satisfactory images are to be obtained. In the case of metallurgical samples this was not possible, though the need for the high resolution of the electron microscope was quite evident. This led to the development of an instrument designed specifically for examining the surface of opaque specimens. The new instrument is known as the scanning electron microscope and differs basically both from the standard electron microscope and the conventional light microscope.

In place of forming the complete image simultaneously, the intensity of a single minute picture element, corresponding to a half-tone dot in the printed reproduction of a photograph, is recorded at any one time; as in electric picture transmission and television, the final picture is built up from a great number of such elements of different intensity.

In brief, a succession of electrostatic lenses forms a greatly reduced image of an electron source on the object; the diameter of this "electron spot" is less than 25 millimicrons, corresponding to a single picture element of the final image. The secondary electrons given off by the object where struck by the electron beam measure the relative "brightness" of that particular portion of the object. Returning through the last lens, they fall on an inclined fluorescent screen, whose resulting light emission controls the output current of an electron multiplier. This current, after further amplification, ultimately controls the intensity of the half-tone lines in the image printed by a facsimile recorder, the image being recorded in synchronism with the displacement of the fine electron spot relative to the specimen surface.

Figure 7 shows the voltage supply unit, the control panel of the scanning microscope, the vacuum chamber, and the recorder. With this instrument numerous pictures have been obtained with resolutions of the order of 50 millimicrons, considerably better than can be obtained with the light microscope. A typical example is the micrograph of carbonyl iron (Fig. 8). The structure of the scanning lines is so fine as to be scarcely visible; the contrast is excellent.



FIG. 9. STANDARD VS. DESK MODEL.  
THE RCA TYPE B ELECTRON MICROSCOPE TOWERS  
ABOVE THE EXPERIMENTAL DESK MODEL BESIDE IT.

While the replica technique of examining metallurgical surfaces has to a large extent surpassed in resolution the results obtainable with the scanning microscope, the development of the latter instrument continues.

*Small electron microscope.* Recently there has been a demand for an electron microscope of simplified design which could be used conveniently as a tool for routine work. To answer this demand a small desk-type electron microscope has been developed in this laboratory. A photograph of this instrument in comparison with a standard electron microscope is shown in Figure 9. Figure 10 is a diagrammatic cross section of this new instrument.

The length of the microscope column, which is inclined so as to present to the observer the final image on the transparent viewing screen at a convenient angle, is only 16 inches. The objective and projector lenses form part of the same magnetic circuit and are excited by a single coil. The magnification by the instrument is 5,000. Since, however, its limiting resolution, and hence its useful magnification, are of the same order as the corresponding quantities

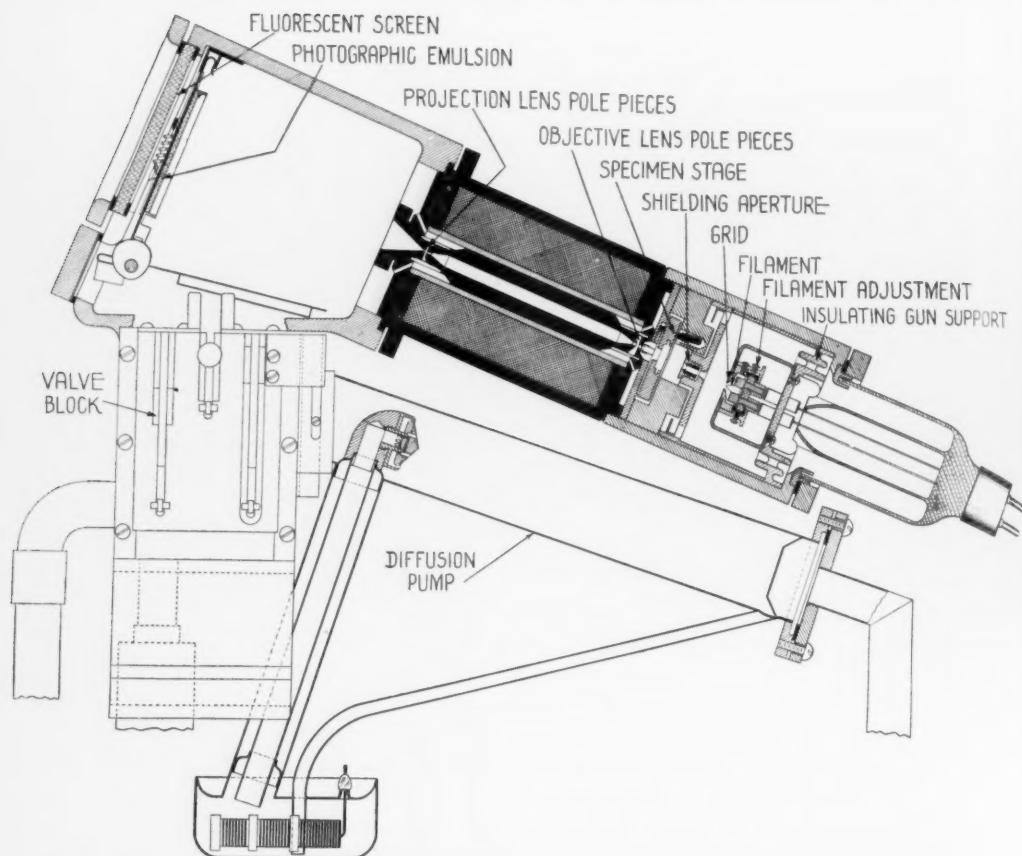


FIG. 10. CROSS SECTION OF THE DESK TYPE ELECTRON MICROSCOPE

of the standard instrument, electron micrographs obtained on fine-grained photographic materials at this relatively low magnification may usefully be enlarged by a factor of about 20. Magnifications lower than 5,000 may be obtained by changing the mechanical setting of the lenses. The operating voltage remains fixed at 30,000 volts. Focusing is accomplished by adjusting the coil current. Since the total volume of the microscope is only about one liter, which can be evacuated in about two minutes, no airlocks are required in either the specimen or the photographic chamber. Mounted on a standard desk, the compactness and simplicity of construction of this small electron microscope make it extremely easy to manipulate and very favorable for routine observations.

*The electron microanalyzer.* In the preceding sections we have indicated several

times that the information which the electron microscope gives can be summed up by the three words—size, shape, and structure. It has also been indicated that the electron optical technique may be applied to answer some of the other problems which arise in connection with research work on finely divided material. Another instrument which has been developed for this purpose is the electron microanalyzer (Fig. 11). With this instrument a chemical analysis of an extremely minute area of an electron microscope specimen can be made. It utilizes a fine electron probe produced in the same way as in the scanning microscope. As the electrons of the probe pass through the selected area of the specimen, some of them suffer a loss in energy which is specific for each element of the periodic table. By detecting and measuring the specific losses in velocity by means of a magnetic electron velocity

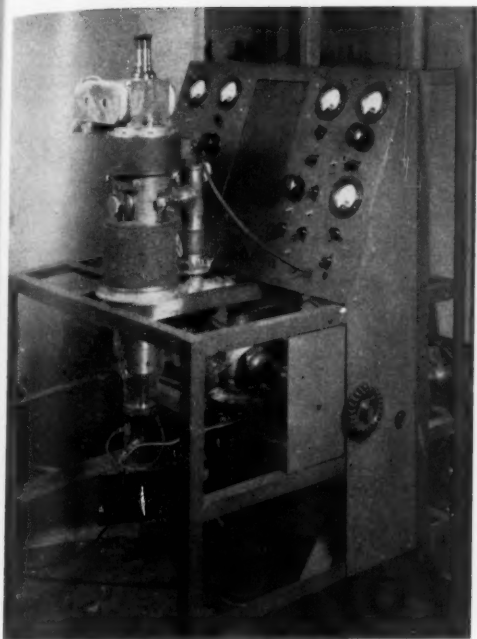


FIG. 11. AN ELECTRON MICROANALYZER

analyzer incorporated in the instrument, it is possible to determine all the elements present in the specimen area being analyzed. An electron microscope is incorporated in the instrument enabling the operator to observe the specimen as a whole and select the area which he wishes to analyze. While this instrument is still in its early stages of development, the results obtained indicate that future electron microscopists will be able to add chemical symbols to their micrographs.

#### APPLICATIONS

The number of problems to which the electron microscope has been applied<sup>1</sup> in the few years of its existence is literally astounding. In the field of biology they run the entire gamut from the larger anatomical structures of insects through diatoms, cell structures, and bacteria to virus and large organic molecules. In the field of chemical particles it has been used to examine all types of finely divided materials from extremely thin evaporated films through fine colloidal particles and pigment to the larger chemical particles and crystals. With the development of the replica technique the study of the surfaces of materials of all types has also become one of the major applications of the electron microscope. A large part of this work has naturally been of an exploratory type, and many of the results have been incidental to the initial "feeling out" of the possibilities of the instrument. This phase of the application of the electron microscope is now passing, and many investigations of fundamental importance are being undertaken.

In a brief general review of the subject of electron microscopy it is not possible to present a complete survey of the research accomplishments of this new science. In the following discussion, only a few representa-

<sup>1</sup> For a fairly complete list of the applications of the electron microscope, the reader is referred to the bibliography in the *Journal of Applied Physics*, Vol. 14, pp. 522-531, 1943, by C. Marton and S. Sass.

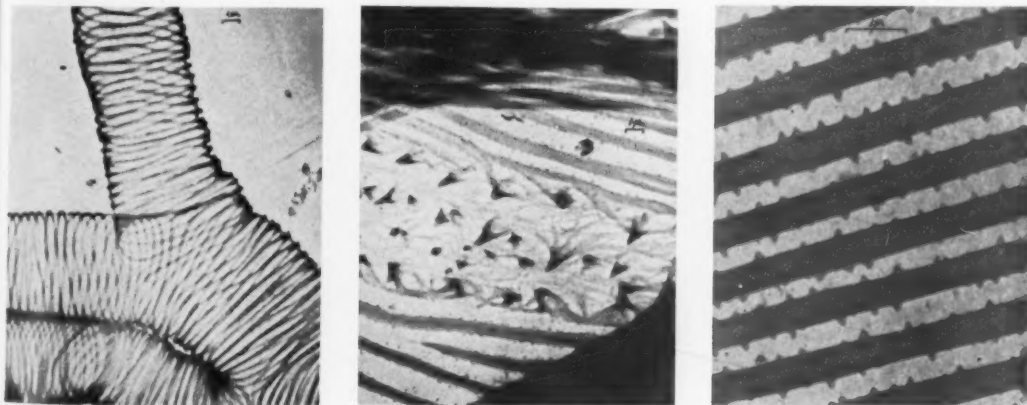


FIG. 12. ELECTRON MICROGRAPHS OF THE TRACHEAE OF A MOSQUITO LARVA

NOTE THE STRUCTURE OF THE SPIRAL BANDS (TAENIDIA) OF THE AIR TUBES (TRACHEAE) POSSESSED BY ALMOST ALL INSECTS. THE ILLUSTRATION ON THE RIGHT IS MAGNIFIED ABOUT 8,300 $\times$ ; THE OTHER TWO, 2,480 $\times$ .



FIG. 13. *VIBRIO SCHULKYLLIENSE*  
RIVER BACTERIA SHOWING INTERNAL STRUCTURES  
AND THE FLAGELLA. MAGNIFICATION ABOUT 19,750 X.

tive examples of the application of the electron microscope in the various fields in which it has been used will be described.

In the field of biology the electron microscope has been used for some rather cursory examinations of some of the structures of insects. Figure 12 is a series of three micrographs of the tracheae of a mosquito larva and clearly indicates the manner in which the electron microscope can be used to determine the finer morphological details of such structures. The investigations up to the present have been confined to the examination of those parts of insects which, when removed from the insect as a unit, can be examined without further preparation. While some preliminary attempts have been made to examine material which must be sectioned, the results have not been encouraging.

Organisms which normally consist of a single cell, such as diatoms and bacteria, are ideal for observation in the electron microscope. As a result of the increased resolving power of the electron microscope, various types of bacteria can be seen to possess easily recognized characteristics. Consequently Dr. Stuart Mudd and a number

of co-workers at the University of Pennsylvania are undertaking an extensive program to investigate and catalogue the morphology of a large number of types of bacteria. This group has already published several papers describing the appearance of various bacteria under the electron microscope. Figures 13 and 14 are examples of the results being obtained.

The extremely minute viruses which cause a number of common diseases in plants and animals have been known for a number of years. More recently some of these viruses have been obtained in a relatively pure form and many of their properties determined. Before the advent of the electron microscope this work was analogous to "flying blind over unknown territory." In spite of this apparent handicap many exact measure-

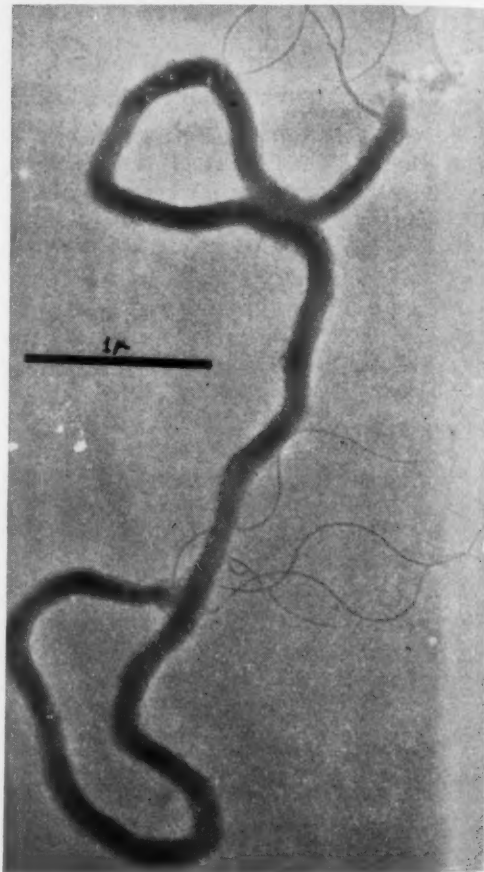


FIG. 14. *TREPONEMA PALLIDUM*  
A PORTRAIT OF A SPIROCHETE, THE PATHOGEN OF  
SYPHILIS. NOTE THE FLAGELLA. ENLARGED 25,700 X.

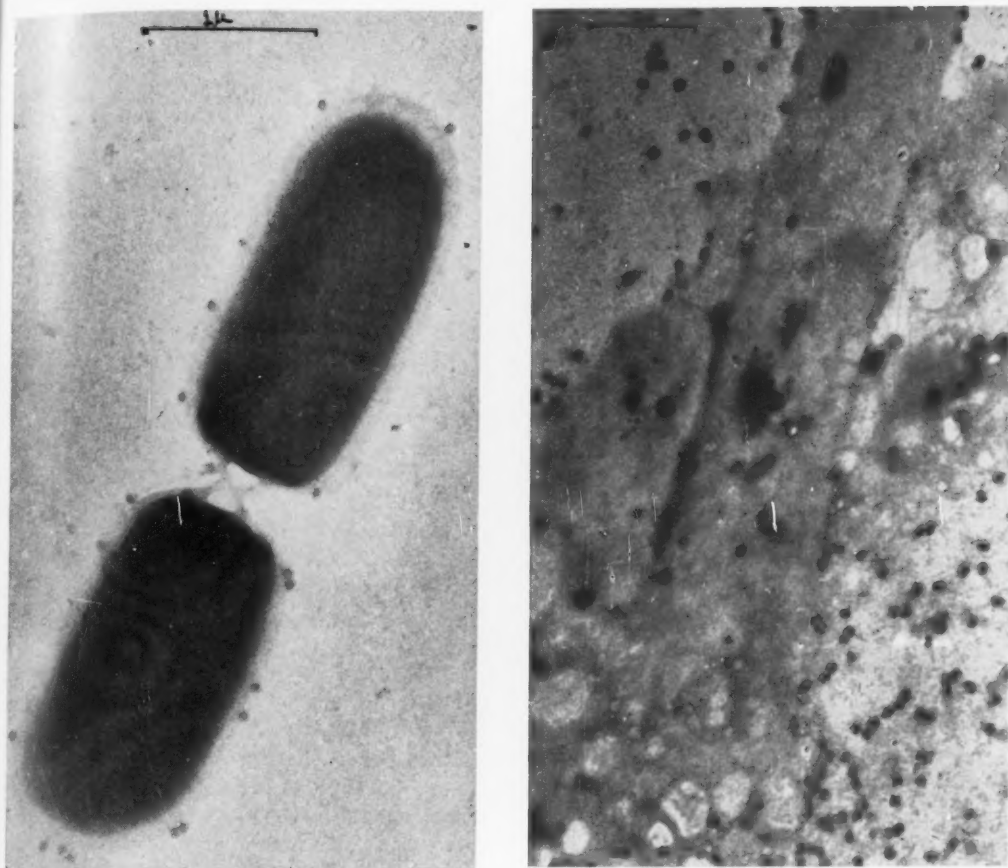


FIG. 15. BACTERIOPHAGE DESTROYING *ESCHERICHIA COLI*

Left, AFTER 15 MIN. CONTACT WITH BACTERIOPHAGE PARTICLES (24,400 $\times$ ); right, AFTER 23 MIN. (13,300 $\times$ ).

ments were made and later when the viruses were observed for the first time in the electron microscope, these measurements were found to be extremely accurate. An outstanding example of the application of the electron microscope to the virus problem, and one in which the results obtained surpassed anything possible by indirect methods, is found in the study of bacteriophage. It was known that the bacteriophage particle was a type of virus which could lyse (destroy) the bacteria for which it is specific. Nothing, however, was known regarding the mechanism of the destruction. By applying the electron microscope to the problem, Luria, Delbrück, and Anderson were able to produce a series of micrographs which not only made the bacteriophage particle visible for the first time but also showed that it had

a well coordinated structure in spite of its minute size and showed very clearly part of the method by which the bacteriophage reproduced itself through the destruction of its host. Such a sequence of micrographs is shown in Figure 15. It can be seen how one or more bacteriophage particles become attached to and perhaps enter a host cell. After an interval of some fifteen to twenty minutes the host bacterium appears to disintegrate and a large number of newly formed bacteriophage particles, along with other material, are expelled.

The next step down on a size scale brings us in the range of the large organic molecules. A number of these which are large enough to be seen with the electron microscope have already been photographed. Little has been done, however, in this particular

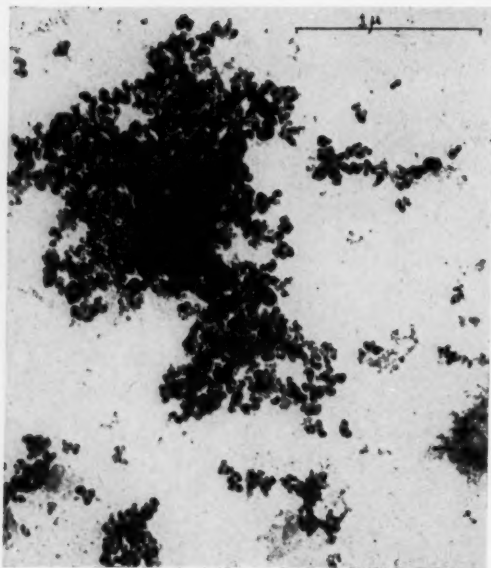


FIG. 16. COMMERCIAL GAS BLACK  
SHOWING PARTICLE SIZES. MAGNIFICATION 25,200 $\times$ .

field because the resolving power of the electron microscope is of the same order of magnitude as the particles being observed. This means that the particles themselves do not appear sharp and for the present at least there is no possibility of observing any structure.

The application of the electron microscope to the field of industrial chemistry is probably the most important of all and also the most direct. It is concerned almost exclusively with the correlation between the size, shape, and structure of finely divided particles and the physical and chemical properties of the bulk product. The particles studied range in size from as large as several microns down to molecular dimensions. This range includes almost every material that occurs in a particulate form. By means of the electron microscope particle size distributions can be determined quite accurately. Measurements obtained in this way have the advantage that the shape of the particles is visible (Figs. 16 and 17). It is in the application of the electron microscope to industrial chemistry that the electron diffraction adapter is of most use as an auxiliary means of obtaining information. Transmission-type electron diffraction patterns of finely divided crystalline materials

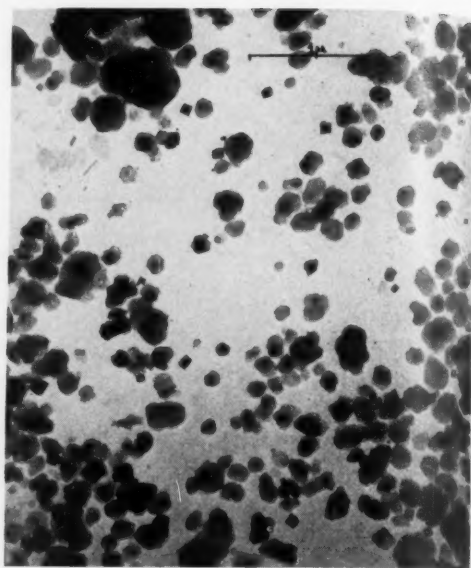


FIG. 17. A CALIFORNIA CLAY  
THIN FLAKES AND CUBES. MAGNIFICATION 15,900 $\times$ .

are very readily obtained and give an accurate check on the composition of the material being examined.

As soon as the high resolving power attainable with the electron microscope was demonstrated, it became apparent that metallurgists had a number of problems in which

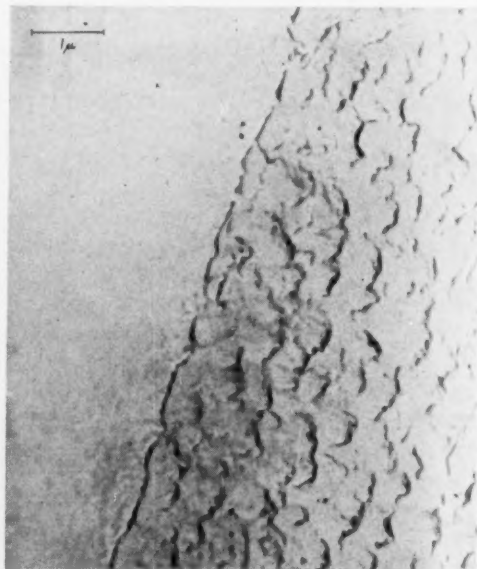


FIG. 18. SURFACE OF BRASS  
REPLICA TECHNIQUE DISCLOSES A GRAIN BACTERIA

this increased resolving power would be of great value. Although, at the time, it did not seem possible to observe metal surfaces directly by means of high magnification electron optical systems, an indirect technique of doing so was forthcoming almost immediately. This involved the preparation of a thin plastic replica of the surface to be examined. The replica was itself of the optimum thickness for examination by means of the electron microscope. The method has been developed rapidly, until, at the present time, replicas can be produced which preserve the detail of the original specimen down to the limit of the resolving power of the electron microscope. Figure 18 is an example of this type of work.

In the preceding paragraphs a very brief survey has been made of the rapidly growing science of electron microscopy. It has been shown how the electron microscope can be used to extend the usefulness of the light

microscope in almost every field where the latter instrument is applied. Some of the auxiliary types of electronic equipment which are being developed around the electron microscope have also been described briefly. When the electron microscope was first introduced to practical use about three years ago, it stirred up considerable interest. Some skepticism was evident particularly in discussions on the interpretation of the images. On the other hand, some workers found immediate solutions to old problems and considered the instrument a "modern miracle of science." After three years of intensive research by what is still a relatively small group of workers, the electron microscope is slowly but surely being established in its true role: that of a high-powered aid to our vision. It is only when the electron microscope is used as a visual guide to and a check on the complete investigation of a problem that its maximum value to science is realized.

#### ZWORYKIN AND HILLIER



VLADIMIR KOSMA ZWORYKIN, E.E., Ph.D., Sc.D., is Associate Research Director, RCA Laboratories, Princeton, New Jersey. He was born in Russia in 1889 and received his degree in electrical engineering at the Petrograd Institute of Technology in 1912. Until the outbreak of World War I he continued his studies at the Collège de France in

Paris and during the war he served in the signal corps of the Russian Army. Dr. Zworykin came to the United States in 1919 and was soon employed in research by Westinghouse in Pittsburgh. During that period he became an American citizen and took his Ph.D. at the University of Pittsburgh. In 1929 he became Director of Electronic Research with the RCA Manufacturing Co. and in 1942 the Radio Corporation of America advanced him to his present position. Dr. Zworykin has long been a leader in technological developments in electronics. His books are: *Photocells and Their Applications* (1932), *Television* (1940), and *Electron Optics and the Electron Microscope* (in press). The esteem in which his work is held is indicated by his membership in the National Academy, American Academy, and French Academy of Science, and by the awards that have come to him, particularly the Rumford Medal.



JAMES HILLIER, Ph.D., a research physicist, has been working with Dr. Zworykin at RCA since 1940 on the development of electronic microscopy. Only twenty-nine years ago Dr. Hillier was born in Brantford, Ontario. His undergraduate and graduate work was done at the University of Toronto where he took his Ph.D. in physics in

1941. From 1939 to 1940 Dr. Hillier was a research assistant and demonstrator at the Banting Institute of the University of Toronto Medical School. Like those other young pioneers, Banting and Best, who preceded him at Toronto, Dr. Hillier and Dr. Prebus (now at Ohio State) became pioneers, not in the field of medicine, but in electronic microscopy, which will certainly aid medical research. At Toronto in 1939 Dr. Hillier and his associates were the first on this continent to build a successful electron microscope of high resolving power. For RCA he designed the first commercial electron microscope to be made available in the United States. He has worked on several of the "associated developments" described in the present article and is now developing a new electronic tool for microanalysis. Already an Electron Microscope Society of America has been formed, of which Dr. Hillier is now vice president.

## CLEVELAND—A GREAT LAKE'S PORT

By E. WILLARD MILLER

CLEVELAND, situated at the mouth of the Cuyahoga River on Lake Erie, lies in one of the best commercial locations in America. Located strategically between the Lake Superior iron ores and the Appalachian coals, Cleveland has been able to solve its problems in handling these bulk commodities efficiently and easily. It has become one of the country's leading ports, handling as much tonnage in seven months as Boston, Philadelphia, or Baltimore do in twelve. Cleveland is also frequently considered the financial heart of the Great Lakes. At present more than 320 ore-coal boats, divided into 15 or 16 major fleets, are largely controlled from the offices located on the city's public square. Between 5,000 and 6,000 vessels enter and leave the port each year carrying freight valued at \$225,000,000 to \$250,000,000.

*Early development of the port.* Nearly every important settlement on the Great Lakes developed at the mouth of a river or stream which offered protection from wind and waves during loading and unloading of vessels. As the New England Yankees came along the shore of Lake Erie in 1796 looking for a place to settle, they stopped at the mouth of the Cuyahoga because of its harbor possibilities. Trade began almost immediately in furs bought from the Indians, and in 1800 Cleveland was made a port of entry. However, even at this early period certain natural barriers in the harbor restricted the free movement of vessels. Across the river mouth a sand bar obstructed the entrance for a greater portion of the year. The spring floods usually destroyed it, but the bar appeared again during the low water stage of summer and autumn. Boats, therefore, frequently had to anchor outside and unload into scows and lighters.

The first plan to improve the river harbor came with the beginning of construction in 1825 of the Ohio and Erie Canal, which was to extend from Cleveland to Portsmouth, Ohio. Thus, in 1825, the Federal Government appropriated \$5,000 for the construc-

tion of a pier which began about 500 feet east of the mouth and extended into the lake for 600 feet nearly at a right angle to the shore. The pier was unsuccessful because sand filled in behind it. In 1827 an additional \$10,000 was granted in order to eliminate several meanders in the lower two miles of the stream where silting took place. The new direct channel began where a bend carried the river within 1,000 feet of the lake. A dam was built across the stream at low-water stage, and with the aid of some digging the next high water cut a straight channel to the lake. Gradually the mouth of the old river filled in, and the upper portion of this bed is now used as a place of anchorage and wharfage. By 1840 about \$75,000 had been spent for harbor improvements, docks, and warehouses.

With the completion of the Ohio and Erie Canal in 1832, Cleveland gained undisputed leadership among the Ohio ports and was second only to Buffalo on the Great Lakes. The increase in commerce was immediately noticeable, particularly in passenger service, for the new waterway enlarged the possibilities of lake travel and freightage by providing a means of carriage into the State and on to the south by way of the Ohio and Mississippi Rivers. A large section of the country was provided with an outlet for products hardly marketable before. In 1838 more than 58,000 tons of goods, valued at \$2,444,000, were exported. Of these commodities flour and wheat had the greatest value and pig iron and lumber the largest bulk. In the same year 67,600 tons were imported, more than 90 per cent of which was merchandise. As a result of Cleveland's advantageous position, her population grew from 600 in 1820 to 17,034 in 1850.

*Increase in iron ore traffic.* Although the development of lake transportation was steady and important for the period, it was still limited in 1840. Because of the lack of plentiful harbors and the storminess of Lake Erie, only 48 schooners, 8 steamboats, and 2

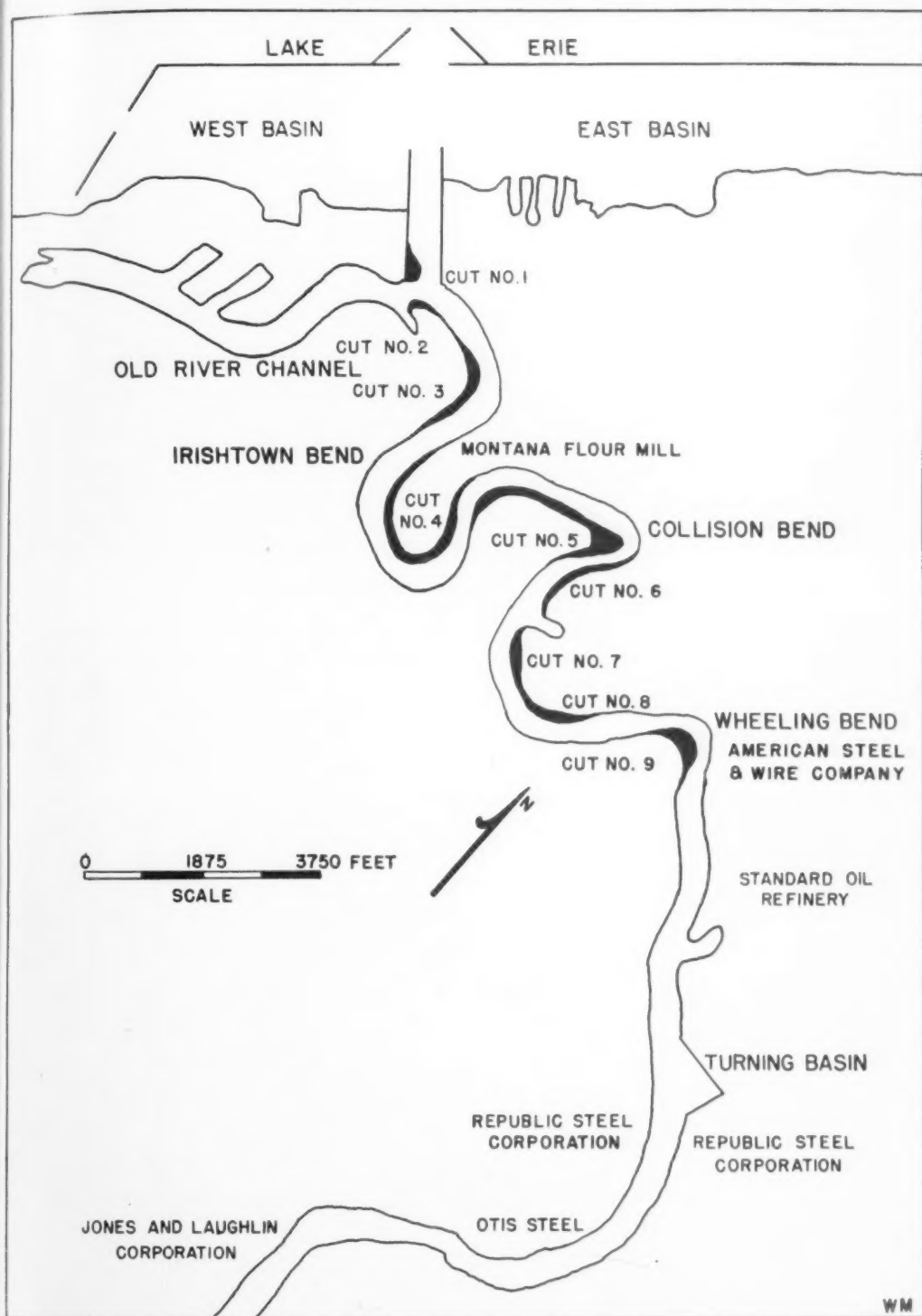


FIG. 1. HARBORS OF CLEVELAND, OHIO.

OUTER HARBOR OF THE WEST AND EAST BASIN IS THE COMMERCIAL HARBOR. INNER HARBOR ALONG THE CUYA-HOGA IS THE INDUSTRIAL HARBOR. SHADED AREAS SHOW WHERE THE RIVER CHANNEL WAS WIDENED IN 1940.



FIG. 2. THE MOUTH OF THE CUYAHOGA RIVER.

brigs plied the lake in 1838. Lake traffic became tremendous only after the discovery and development of the iron and copper ores in the upper lake region in the 1850's, and the shift of the iron and steel industry to western Pennsylvania in the 1860's. Since

Cleveland was one of the largest and most prosperous cities on the lakes in the 1850's, much of the capital to develop the ore resources came from its business men. From 1850 to 1890 Cleveland groups maintained a near monopoly in iron trade, for they con-



FIG. 3. INNER HARBOR NEAR HEAD OF NAVIGATION.



FIG. 4. INNER HARBOR DOCKS AND BLAST FURNACES.

trolled the Marquette iron range, the only important producing area. The golden era in Cleveland's ore trade came from 1880 to 1890 when the number of its vessels increased from 175 to 241 and the tonnage from 64,287 to 176,804. In 1890 the total United States

tonnage constructed aggregated 294,122, of which 108,525 were built on the Great Lakes; of this amount Cleveland's shipyards built 39,095 tons, 13 per cent of the total and 36 per cent of the entire tonnage of the Great Lakes. The Cleveland district, with the



FIG. 5. AUTOMATIC UNLOADING LIMESTONE BOAT AT THE MOUTH OF THE CUYAHOGA.

single exception of the Clyde region of Scotland, was the largest shipbuilding point in the world. Cleveland business men controlled all the Lake Erie docks, except those at Erie and Buffalo, and owned at least three-fourths of the vessels in the ore trade.

*Rise of competition and harbor problems.* During the 1890's a number of problems developed that gradually threatened Cleveland's position in lake trade. With the discovery of other iron ore ranges in the 1880's and particularly the Mesabi Range in 1890, Cleveland business interests no longer controlled the entire ore region, and other lake ports began a period of rapid expansion.

Besides the increasing competition, another problem developed which was to plague Cleveland for nearly 50 years. As long as lake boats remained small, the Cuyahoga River, Indian name for crooked river, could handle the traffic efficiently. However, the newer, longer vessels exceeding 480 feet experienced great difficulty in negotiating the curves, which between the mouth of the river and a point two miles upstream totaled 855 degrees of curvature or two and three-eighths circles. Because of these curves and because the ships had to be towed (self-propulsion would have churned up mud and caused

shoaling), bulk freighters required about five hours to travel from the mouth of the Cuyahoga to the upper steel plants, a distance of five miles. After delivering their cargo, the freighters had to be towed out stern first, for they could not turn in the river. Towage costs were approximately \$400 a round trip. Other operating expenses averaged about \$100 per hour so that the cost of a round trip varied from \$1,200 to \$1,500. Another problem created by the sharp curves was the lack of river frontage for docks since boats needed the entire width of the Cuyahoga to move around the bends. Many lake captains made the statement that they would rather go to any port on the lakes other than Cleveland.

*The modern harbor.* The present harbor at Cleveland is divided into two parts, a breakwater-enclosed area of the lake called the outer harbor and the lower stretches of the Cuyahoga, the inner harbor (Fig. 1). The improvements of the inner harbor, which handles about 90 per cent of the traffic, was delayed long past the time of imperative necessity. The delay was partially due to the vagueness of a general policy as to division of responsibility among the Federal, state, and city governments. In the case of

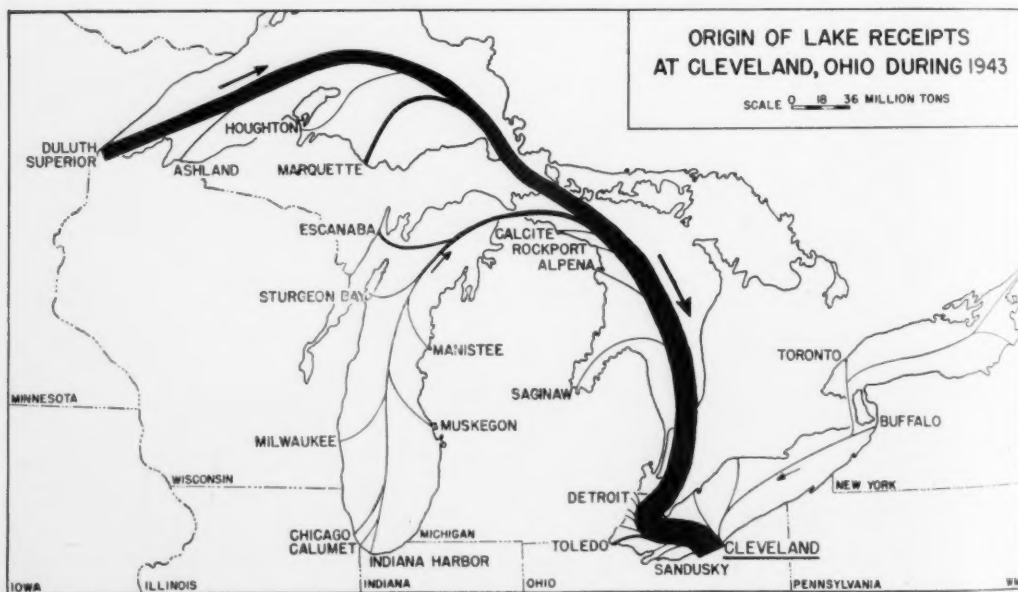


FIG. 6. ORIGIN OF LAKE RECEIPTS AT CLEVELAND DURING 1943.

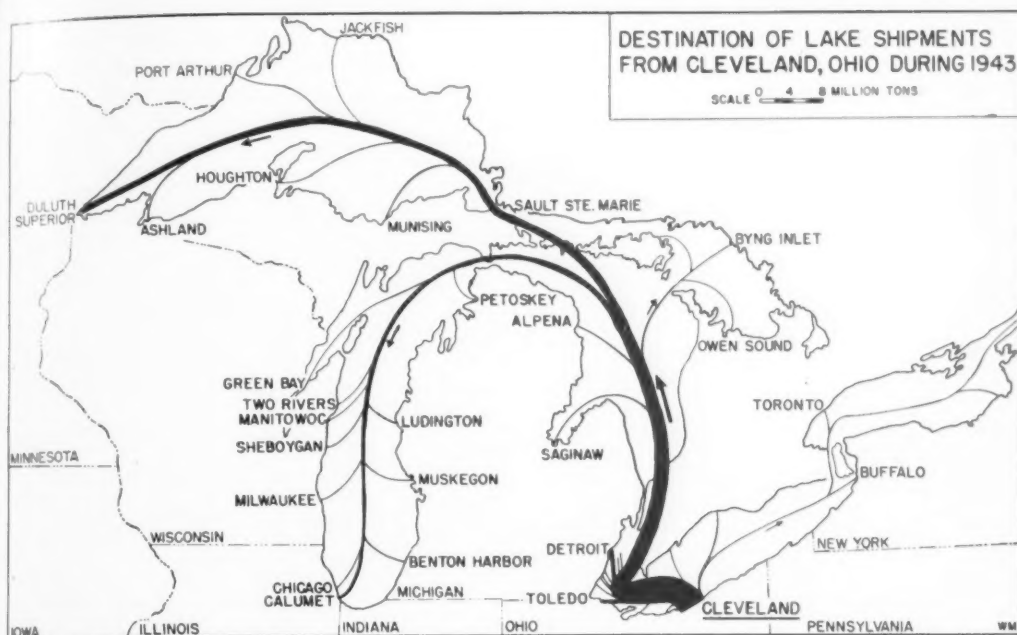


FIG. 7. DESTINATION OF LAKE SHIPMENTS FROM CLEVELAND DURING 1943.

Cleveland the Federal Government improved only the outer harbor; the inner, or river, harbor remained the responsibility of the city. Following this plan, the Federal Government, under the authorization of River and Harbor Acts of 1875, 1886, 1917, 1935, and 1937, completed the construction of an extensive breakwater, which ranges from 1,700 to 3,500 feet from the shore line and protects an area of 1,300 acres of water. The lake harbor is divided into an east basin, which is open the full width of the east end, and a west basin, which is partially closed on the west. The outer harbor has only a few piers and is used mostly for passenger vessels, repair docks, and warehouses.

Although the outer harbor developed a long protected shoreline, it has played a rather insignificant part in the lake traffic of Cleveland, for the heavy industry is concentrated on the flats along the Cuyahoga (Figs. 2, 3, 4, and 5). Little was done to improve the inner harbor until the latter part of the 1930's, and as a result the port has suffered a permanent loss of tonnage in certain commodities, particularly coal. From 1920 to 1940 lake traffic as a whole increased 65 per cent, while Cleveland's portion decreased 11 per cent. After considering eight

separate plans between 1912 and 1937, the necessary improvements were begun in 1939. They included cutting back nine of the sharpest bends (Fig. 1), widening the channel so that nowhere is it less than 90 feet and in places widens to 270 feet, the construction of a turning basin, 17 feet deep and 600 feet wide, 4.75 miles upstream (Fig. 1), and raising or rebuilding low railroad bridges so as to increase safety and speed of lake vessels. A system of docks with a total length of about 13 miles has been laid out, about half of which, containing 43 of the 58 wharves and docks in the harbor, is now in use. Engineers have estimated that 70 years ago the cost of straightening the river would have been about \$350,000; the modern improvements, including the destroying and reconstruction of bridges, buildings, and docks, cost approximately \$11,000,000.

*Commerce.* The modern commerce of Cleveland consists chiefly of bulk commodities, such as iron ore, coal, coke, crushed stone, sand, and gravel, although the movement of petroleum products, automobiles, and manufactured iron and steel products is increasing in importance. The average tonnage of all traffic handled for the prewar

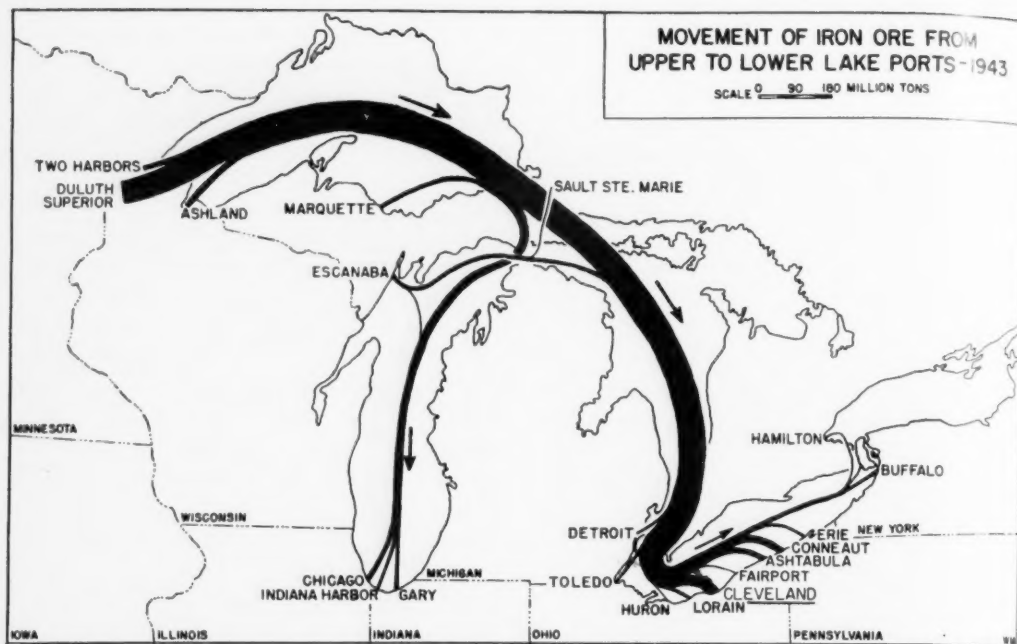


FIG. 8. MOVEMENT OF IRON ORE FROM UPPER TO LOWER LAKE PORTS IN 1943.

period 1929–1938 amounted to 10,965,340 tons per year, a decrease from the 12,219,249 tons handled annually from 1920 through 1928. Tonnages, however, have fluctuated greatly from a low of 4,234,525 tons in 1932, a depression year, to 17,385,842 in 1937. Since the beginning of World War II in 1939, the tonnage handled at Cleveland has increased from 25 to 30 per cent, due largely to the greater shipments of iron ore (Figs. 6 and 7). Fluctuation in tonnage from year to year illustrates the responsiveness of lake traffic to changes in general economic conditions.

Of the lakewise receipts, iron ore represents between 75 and 80 per cent of the total; as a result Cleveland has remained the largest iron ore port on the lower lakes. The receipts of this commodity averaged 6,583,164 tons per year from 1929 to 1938 in comparison with a total average tonnage of 8,357,481 received during the same period. Fluctuation in tonnage of iron ore is marked; in 1929, a peak year, 11,139,432 tons were received, whereas only three years later receipts of iron ore were only 963,840 tons. Since 1939 all previous tonnage records have been surpassed. In 1942, 13,799,639 tons and in 1943, 12,423,308 tons were received (Fig.

8). The dominance of Cleveland as the leading iron ore port lies in its financial control of the iron-coal fleets, its early start, and in the large consumption of iron ore in local furnaces along with its favorable position in supplying ores needed in the Pittsburgh district, the Shenango Valley, and the Stubenville area. Although local mills use between 35 and 40 per cent of the ore received, Cleveland normally sends more ore to the interior iron and steel centers than any other lake port.

Crushed stone is second in tonnage of the commodities handled, averaging over 800,000 tons per year, approximately 10 per cent of the total receipts. Cleveland is second only to Buffalo in the amount of stone handled. Most of the crushed stone originates at Calcite, Rockport, and Alpena on Lake Huron and at Marblehead on Lake Erie. Petroleum products, mostly gasoline and fuel oils, have been increasing in recent years. The remaining tonnage of lakewise receipts consists of scrap iron, iron and steel shapes, pig iron, coal tar, sulphur, cement, flaxseed, and phosphate rock.

One of Cleveland's greatest problems is the difference between lakewise receipts, which total 75 per cent of all traffic, and lake-

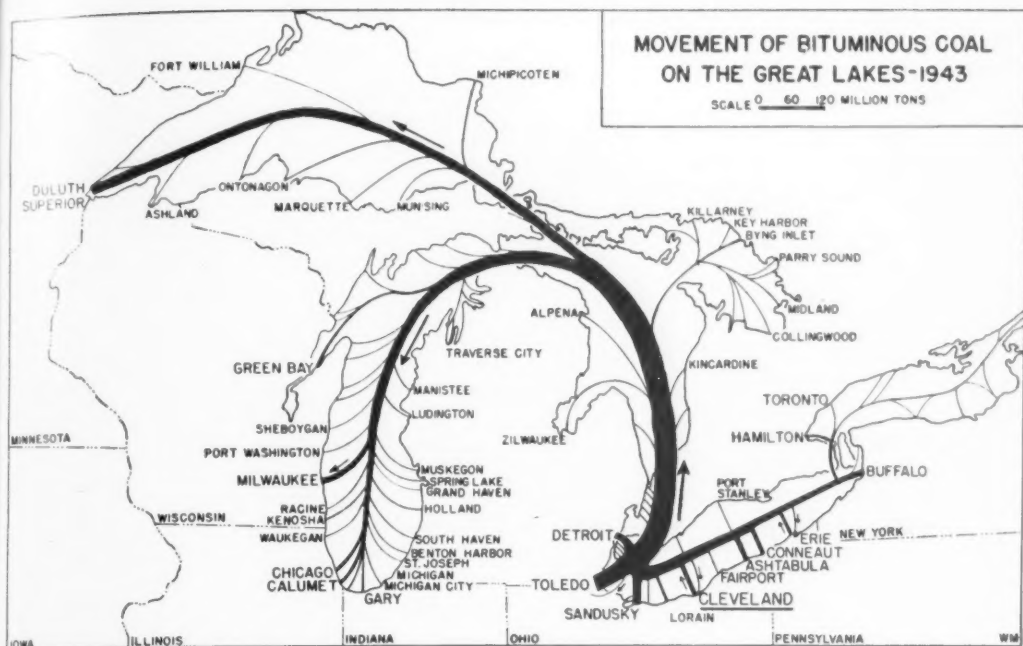


FIG. 9. MOVEMENT OF BITUMINOUS COAL ON THE GREAT LAKES IN 1943.

wise shipments which account for 16 to 17 per cent of the water-borne commerce. This means that many vessels must leave Cleveland without a cargo. Of the lakewise shipments, coal plays a dominant role, usually consisting of 70 per cent of the total. Of the lake ports, Cleveland is sixth in tonnage of coal shipped, averaging 1,250,000 tons per year. The large coal traffic of the lakes developed when Cleveland's harbor facilities were poor, and other lake ports, particularly Toledo, gained most of this trade (Fig. 9). Cleveland's industry also consumes a large percentage of the coal coming to the city. The shipment of iron and steel in rolled form, bars, structural steel, pig iron, and manufactured articles account for 20 per cent of the total. The principal ports of destination for these products are Ecorse, Detroit, and Saginaw, Michigan; Calumet Harbor, Illinois; and Duluth, Minnesota. Petroleum products are also important in

outbound traffic, as well as automobile bodies and trucks.

Cleveland's trade is almost entirely domestic; only a limited amount of export and import trade is developed with Canada. The principal imports are sand and gravel, paper, newsprint, flaxseed, and scrap iron, while coal comprises 95 per cent of the exports.

The water-borne traffic of Cleveland is directly related to the iron and steel industry. With the improvements of the harbor, raw materials can be assembled in Cleveland at a cost as low as any place on the Great Lakes. This was demonstrated when the Republic Steel Corporation in 1939 chose Cleveland as the site of its new continuous wide-strip mill. Although the port has been greatly handicapped in the past, the improvements make it possible for Cleveland to compete with harbors that can accommodate the largest freighters, thus marking a new era in the handling of lake traffic.

# SCIENCE IN FRENCH CANADA

## I. INTELLECTUAL TRADITIONS

By PIERRE DANSEREAU

THE war is showing the nations of North and South America how much they have in common, how truly American they all are. Together they have agreed to defend their land, their freedom. But it does not follow that freedom has the same meaning for all of us. Indeed, the material, intellectual, and spiritual background of each American nation is such that its pattern of life, the very fabric of its individuality, is different from that of its neighbor, not to mention nations at other latitudes.

"One world!" is boldly proposed by a great American politician. "*Liberté, égalité, fraternité!*" said the French republic of yesterday, and no doubt that of tomorrow will re-echo the motto. But equality and liberty, if they are basically the same everywhere, have different components in the minds and consciences of different peoples.

No peace, no freedom, no permanent international concord can exist without the recognition of this diversity. Are we not fighting against the will of one nation to impose its way of life upon all other nations? That nation thinks that it knows best. Such is the justification of all dictatorship, of all authority, for that matter. But that attitude is shared—it sometimes seems unconsciously—by people who profess truly democratic ideals. Was it not Jean-Jacques Rousseau himself (whose political convictions are quite above suspicion) who said: "*Il faut forcer les hommes à être libres?*"—an over-realistic and very dangerous principle, to say the least.

There can be no peace but in mutual understanding. And that in turn can come only from an unprejudiced approach to the ways and habits of other nations, and the appreciation of the genuine elements of their culture even when these spring from an uncongenial religious or intellectual, or even political, background. That, I know, is very much to ask, too much perhaps. But who does not hope for some grain of wisdom to be

sown and to germinate in these days of affliction?

My purpose, however, is not to plan a better world and even less to tell American scientists how broad or how open their minds should be. The aim of this article is to draw a brief outline of science and scientific life in French Canada and to cite a few facts not generally known to our American colleagues. It also attempts to give some explanation of French-Canadian intellectual development, especially in the field of science.

*The "cours classique."* After 1763, when Canada was ceded to England by France, there remained some 60,000 colonists. For three-quarters of a century these people, whose numbers steadily increased, were largely deprived of intellectual leadership. Relations with France had been completely severed. No books in a language they could understand were available. The only educated men were the priests and even they, in some cases, were so only by comparison. Education was entirely in the hands of the clergy. The bishops created the *petits séminaires*, in which young men were taught Latin and Greek, French and a little mathematics, and the rudiments of science. These institutions were above all, and some of them have remained almost to this day, a mere stepping stone to the *grand séminaire*, where formal studies in theology lead to ordination in the priesthood.

It is therefore evident that this *petit séminaire* (which assumed the role of both high school and college) dispensed an education in harmony with its basic purpose: the training of the clergy. Its program centered about the Greco-Latin humanities and the philosophy of Aristotle and Saint Thomas Aquinas. The rigid discipline of the classic authors, both in style and logic, was the mainstay of that system. The whole weight of the mind, so to speak, was made to bear on synthesis, on the end product of intelle-



THE MAIN TOWER OF THE UNIVERSITÉ DE MONTREAL

*André de Tonnancour, Montreal*

tual endeavor which has to do with the assembling of facts, not with their unearthing. In fact, there was very little in this method which had any earthiness about it, the great romantics of French literature themselves being regarded with much suspicion by the masters.

One must bear in mind the relative universality of this desiccation process under its many forms in the Victorian era. Its French-Canadian expression was, on the whole, less dismal than one might think, the natural good humor and love of life of the race tending to check all excessive rigidity with characteristic French realism.

However that may be, the intellectual gymnastics involved in intimate and everyday contact with Xenophon, Cicero, and Pascal produced men of considerable intellectual versatility. Some were remarkable orators, but none were good businessmen and few were able technicians.

*The "liberal" professions.* However, all students of the *cours classique* did not become priests, and from the beginning many of them were oriented towards law or medicine. In fact during a very long period when a sort of superstition attached to these so-called liberal professions, all others were notoriously less "honorable." It hardly seemed worth while putting a boy through the relatively expensive *cours classique* to make anything less of him than a *docteur* or an *avocat*.

It would be somewhat outside the scope of this brief survey to draw a detailed picture of these two professions. Let it suffice to outline some of the major traits as an illustration of the outcome of the educational system as a whole and of the characteristic intellectual leanings of men who were the very core of the élite.

Civil law in the Province of Quebec is based on the Napoleonic code. The French-Canadian jurist follows French tradition in that he presents and judges his case more in accordance with doctrine than with jurisprudence. This is a significant fact and an outstanding symptom of the vitality of the French-Canadian mentality in a predominantly Anglo-Saxon country where custom and precedent, not theory, are the rule. The

existence and functions of the notary are also typically Latin and do not exist in the other eight provinces of the Dominion.

In medicine an analogy can be found in the current mistrust of exclusive specialization and in insistence on general examination and clinical methods. It is no doubt a direct result of a humanistic upbringing that no function of the human body may be considered separately unless complemented by a general clinical diagnosis. A large number of French-Canadian physicians have carried on postgraduate studies in France, and the influence, both direct and indirect, of French medicine is very much alive in Canadian medical practice today.

Other professions are more recent in the history of French Canada: engineering, agronomy, forestry, accountancy, business management, etc. For many years, there were no schools in his country where a French-Canadian could receive training in these subjects in his own tongue. If he could not afford to go to France, which was often the case, he went to Anglo-Canadian or American institutions. There he found that he had first of all to catch up with the language, and then with some of the facts which his schoolmates had already learned in school or college. He found that his "general culture" was a useful tool, but he also observed that the materials to be wielded were strangely unfamiliar. In fact, he experienced what his masters of the *petit séminaire* had predicted; namely, that his mind was now ready to assimilate, but that he knew very little. His baggage of common scientific facts was slight indeed. More often than not, however, this handicapped student turned out quite well, and in many instances did brilliantly in the end. The founders of French-Canadian schools of engineering, agronomy, forestry, chemistry, and economics all belong to that category: they have been reformers in education and have created institutions of solid scientific standing.

*Religious background.* The priest, however, is the most authentic product of the *cours classique*, or French-Canadian system of education. Primarily it was devised for him and to this day it has essentially fulfilled the purpose of developing those quali-

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F. Gérard Simard, S.J., Montreal

THE NEW BUILDING OF UNIVERSITÉ DE MONTRÉAL ON THE SLOPE OF MOUNT ROYAL  
THE INSTITUTION ORIGINATED IN 1878 AS A BRANCH OF UNIVERSITÉ LAVAL; BECAME INDEPENDENT IN 1920.

ties most necessary to the exercise of his functions.

By the force of circumstances, those functions were very diverse in the past, and they remain so today in many rural districts where the *curé* is the best educated person in his community. His counsel was taken and carried much weight, not only in spiritual matters where his authority is unchallenged, but in domestic, educational, political, and economic matters as well. Very much has been made of the clergy's role in keeping the French-Canadian people distinct by safeguarding their culture along with their faith. Canon Groulx,<sup>1</sup> the foremost exponent of such views, would have us think that the French-Canadian people owe their very existence to the leadership of their Roman Catholic clergy. It may be well to point out, with Albert Pelletier,<sup>2</sup> that the greater credit may well belong not to those in authority, but to the laymen and to the

lower clergy, nearer to the people and more of the people, whose uncompromising attitude was more decisive than the more polished performances of the higher clergy.

The religious background is therefore extremely important in the study of intellectual evolution in French Canada. The very universality of Roman Catholicism facilitates the comprehension at least of some of its elements. We shall not discuss its more intimately religious and mystical aspects; our subject is the intellectual and social influence of the Church as an institution, not its spiritual significance.

Anyone at all familiar with the Church of Rome, and willing to consider it under its historical aspect, cannot but marvel at its unparalleled wisdom. No doubt, to many—and especially to those of a different faith—it appears as a reactionary force. Some widely publicized events have tended to establish this view. But let it be remembered that if Rome silenced Galileo, the French Revolution beheaded Lavoisier. There are appar-

<sup>1</sup> Superscript numbers refer to "Literature Cited" which will appear at the end of Part II.

ently some institutional necessities quite independent of the progressiveness of the organization itself. These are unfortunate, but present in all institutions of long standing, even the most constructive. But this is neither the place nor time to open a debate on such a far-reaching question. Many excellent discussions of this point have appeared, for instance, in Jacques Maritain's recent book, *The Nights of Man and the Natural Law*, 1943, New York.

It is sufficient to say that the Catholic Church has undergone various adaptations, throughout many centuries and in many countries. What we are concerned with is the form it has assumed in French Canada and the bearing of religious pressure on scientific and intellectual life here.

The long-unquestioned position of the clergy as a dominant caste, so to speak, has forcibly introduced a religious element into the acts of everyday life. This of course has

only been possible because the nation as a whole subscribed wholeheartedly both to the Catholic credo and to the authority of the Church. Such grounds are eminently favorable to an encroachment of the clergy on secular affairs. Also such a long-established dominance becomes institutional in character and in the end highly conservative.

The Catholic clergy in Quebec has produced some of the most brilliant, intelligent, and constructive minds Canada has known. It comes as no surprise that these same men—much as the Tories of Old England, whose contribution to the grandeur of their country is not questioned—were defenders of their class privileges and of the dominance of theology over science.

The people of French Canada have been and generally remain deeply conscious of their religious duties. Today they dispute the clergy's monopoly of education and challenge some of its age-old political teachings.



André de Tonnancour, Montreal

THE NEW BUILDING OF THE UNIVERSITÉ DE MONTRÉAL  
SEEN THROUGH THE OAKS OF MOUNT ROYAL. A SKI-TOW HAS BEEN ESTABLISHED ON THE UNIVERSITY CAMPUS.



L'Université Laval, Québec

THE CENTRAL PART OF OLD UNIVERSITE LAVAL, IN QUEBEC

IT WAS FOUNDED IN 1663 AS A SEMINARY BY MGR. DE MONTMORENCY LAVAL; BECAME A UNIVERSITY IN 1852.

but it is significant that even the avowedly heterodox are religiously minded.

*The minority complex.* The response obtained by the clergy in the exercise of its authority was further enhanced by the necessity for leaders which was, and still is, very keenly felt by French Canadians in all walks of life. I need hardly insist on the fact that a minority, living in self-defense in an imperial state, had to entertain a constant awareness of its problems and stand close by its leaders. Every man was made to feel responsible in some way for the survival and progress of the group as a whole. By the force of circumstances, and especially through the play of imperialist policy, no French Canadian was allowed to forget that he was part of a minority whose rights were forever being questioned, not to say violated,

in a number of small and inconspicuous ways.

Such a restless and often negative attitude is no doubt difficult to understand and seems mean and hopeless to the member of a great, unified nation. However that may be, it makes the need for authority, command, discipline, and what rightist parties call *order*, much more imperious than the need for equality and freedom. Indeed these, at certain moments in the life-history of a minority, seem remote and maybe hopeless goals, if not beautiful but meaningless symbols.

It therefore becomes easy to understand that the best intellects that we have produced—especially in the nineteenth century—were drained towards action, mostly political, and not towards the more speculative forms of intellectual pursuit. A keen, if misdirected, sense of duty drew these talented



André de Tonnancour, Montreal  
MGR. OLIVIER MAURULT  
PRESENT RECTOR OF THE UNIVERSITÉ DE MONTRÉAL.

men away from art, literature, and science and into the public arena. Most of them were artisans of *bonne-entente* and worked constructively towards a harmonious development of Canada "*a mari usque ad mare*." Men such as Papineau, Cartier, LaFontaine, and Laurier were essentially men of good will who went to the extreme limit of concession compatible with the dignity of the group they represented. Whether their optimism was well founded remains an open question.

*The anticlerical strain.* Through political channels, however, and not through literary activities, new ideas were introduced which were a menace to clerical supremacy. Louis-Joseph Papineau, the chief leader of the 1837-1838 insurrection, was the initiator of a tradition of rebellion against the all-embracing monopoly of the Church. The spiritual descendants of Papineau have not been very numerous, but they have kept up the struggle all these years and have obtained

many a victory, mostly under the banner of the liberal party.

Such questions as evolution, the rights of strikers, and birth control have given rise to bitter and highly prejudiced debates, where the defenders of so-called liberal views had a hard time of it. On the whole, the tone of these controversies was very much the same as in the Middle West of Mr. Sinclair Lewis at the same period. If the conservatives were capable of pigheadedness, the liberals were at times noted for their naïveté.

Today, the left wing has rallied quite a number of orthodox Catholics, including members of the clergy itself. To them, it seems that there is cause for alarm in the achievement of too much secular power by the Church. They think of France in the nineteenth century and of Spain and Mexico in the twentieth and direct their efforts to self-reform to avoid a revolution.

Today, the dominating influence in French Canada is still ecclesiastical. It covers the whole field of education, whether directly or indirectly. The colleges are affiliated with the two Catholic universities, Laval in Quebec and Université de Montréal in Montreal, but they are actually autonomous, and the universities exercise very little control on either studies or discipline. They merely superintend the examinations and dispense the B.A., which is the culmination of eight years' study.

The youth movements are also in the hands of the clergy. Foremost at all times have been the Jesuits, whose keen sense of organization and excellent psychology have allowed them to control many generations of sound and enthusiastic young men and women.

Some trade organizations also are endowed with an *aumonier*, whose opinion is sometimes decisive in matters not obviously connected either with faith or morals.

The laymen, however, have come into their own in the arts, literature, and primary education. Of course in finance, commerce, the administration of justice and of the state, ecclesiastical intervention is remote if not totally absent.

(To be concluded)

## APPLIED MICROSCOPY OF HAIR

By LEON AUGUSTUS HAUSMAN

THE microscopist was peering through his microscope at some fragments of hair which, under a high magnification, showed evidences of having been subjected to rough treatment of some kind. A few weeks before, the body of a young boy had been found torn and mutilated in a northern forest. Tracks of a mountain lion or cougar were thickly imprinted in the light snow about the body. Tracks of both boy and cougar, leading up to the spot, indicated that for a long time the beast had trailed its victim. A large reward had been offered to the person who could produce the killer. Soon afterwards two large cougars were shot nearby; and two hunters claimed the reward, each one asserting that his beast had been the slayer of the little boy. In the stomach of one of the cougars were found some masses of hair. But such masses in the stomachs of the big cats are not uncommon. Was this particular mass made up of *human* hair? This was the question the microscopist was trying to answer, and finally did answer in the affirmative, even though the hair had suffered some disintegration. The answer had been found after the hair-shafts of the sample had been treated in such a way as to bring out certain structures which it was necessary to examine minutely before attempting to come to a conclusion about the matter. What were those structures? What was it necessary to do to these fragments of hair before they could be made to yield their secret under the microscope? Do the hairs of humans differ from the hairs of other mammals? Do the hairs of mammals in general differ from each other? Do the hairs of humans differ from each other so that personal identification is possible even from minute fragments? Will the microscopic examination of hair fragments enable a microscopist to suggest what sort of treatment the hairs may previously have undergone? These, and many other questions growing out of them, indicate some of the matters to which the microscopist of

mammalian (including human) hair is giving more and more attention.

Another example: this time the microscopist was examining wool fibers from two different samples of fabrics under illumination by polarized light. One sample contained a very large proportion of fibers which were bent, bruised, fractured, frayed at their ends, and showed traces of different dyes in the same fiber. The fibers were, moreover, of varying diameters, and many of them showed cuticular scales (the fine scales which lie on the outside of all mammalian hairs) torn and otherwise changed from their natural form. Such things could not have been seen by the naked eye, but to the eye behind the microscope were clearly revealed. The observations suggested to the microscopist that this particular fabric was made up of materials which had been used in a fabric before, and had been torn apart and subsequently rewoven. The second sample exhibited under the microscope nothing but long, unbent, unbruised, unfrayed fibers, with their scales intact, and all more or less of the same diameter. And the microscopist knew from experience what this state of affairs indicated.

Again (and all these are actual cases), a fur was called by the name of a certain animal. But examination of its component hairs under the microscope revealed that they had been clipped and dyed a deep hue. Furthermore, a study of their cuticular scales, cores, and pigment granules proclaimed that they had grown in the skin of an animal of quite another sort—a clear case of “a different breed of cats.”

How does the microscope reveal these things? It does so by making clear the various minute structural elements that go into the composition of a hair-shaft—structural elements which can neither be eradicated nor altered without leaving plain traces of such tampering. In such ways the microscope often plainly proclaims that identification or

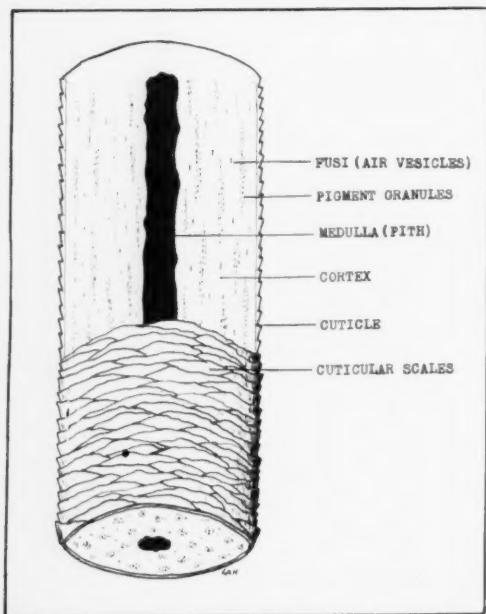


FIG. 1. SECTION OF HUMAN HEAD-HAIR SHOWS THE RELATIONSHIPS OF THE SIX STRUCTURAL ELEMENTS EMPLOYED IN COMPARATIVE MICROSCOPY.

diagnosis, or in some instances even justice, literally "hangs upon a single hair."

Not long ago some burial fabrics of remote and uncertain date were dug up from some South American Indian sepultures. Did the people who wove these fabrics persist until after the Spanish Conquest? This was the question propounded to the heavy brass microscope whose focusing screws the investigator was manipulating. It was known that the Spaniards had brought the first sheep into the region of the graves. Had the microscopist been able to detect sheep wool in the structure of these cerements, it would have helped in the settlement of an historical question.

In a central New England state a biologist is desirous of finding out what mammals inhabit a certain isolated mountain. He collects the excrement of wildeats, which are common there. These nocturnal cats have all unwittingly been acting as the biologists' "corps of collectors," catching and devouring assiduously the smaller mammals of the mountain and leaving in their excrement accurate records, in the shape of masses of hair, of what they have devoured. The microscopist recognizes these hairs and traces

them to their source; and the biologist's census of the mammals of the mountain is the more complete—thanks to his wildeat assistants!

A company making felt mats is having difficulty with the felting, or close and successful compaction, of the finished product. Microscopic examination of the material which felts and holds most satisfactorily reveals that it is filled with the smaller, finer hairs of the animals, whereas the loose, unsatisfactory product is composed of only the larger, coarser hairs of the animals. The finer, smaller hairs possess large, outwardly-projecting scale edges which catch and mesh together well and so help to form successful felts; the larger hairs possess small, tight scales whose edges project hardly at all and hence these hairs do not catch and hold but slip past one another, and the resulting felt is weak and easily pulled apart. Furthermore, the microscope shows that a too-vigorous cleaning process is removing too much of the hard, gritty, extraneous matter from the surfaces of the hair-shafts—is removing something which is actually aiding in the felting of the material.

The structures which go into the make-up of a typical human hair, as well as those of other mammals, are indicated in Figure 1. The outside of the hair-shaft is completely overlain by a layer of thin, transparent scales, known as the cuticular scales. These overlap one another like the scales on the body of a fish or the shingles on a roof. This is the condition in a large number of animal hairs. Or the scales may be set within one another like a pile of glass tumblers, or folded about one another's bases like a pile of calla lilies. For examples of these see Figure 3 and look at Nos. 12, 10, and 11 in the order given. Notice that the free edges of these scales point outward and upward toward the tip of the hair-shaft. Even without a microscope one might guess by fingering a hair that it is barbed. If a hair is held between thumb and forefinger of one hand and pulled between the same digits of the other, the feel of the hair will depend on whether the free end is its tip or its base. If the tip is free, one is scarcely conscious of the movement of the hair between the

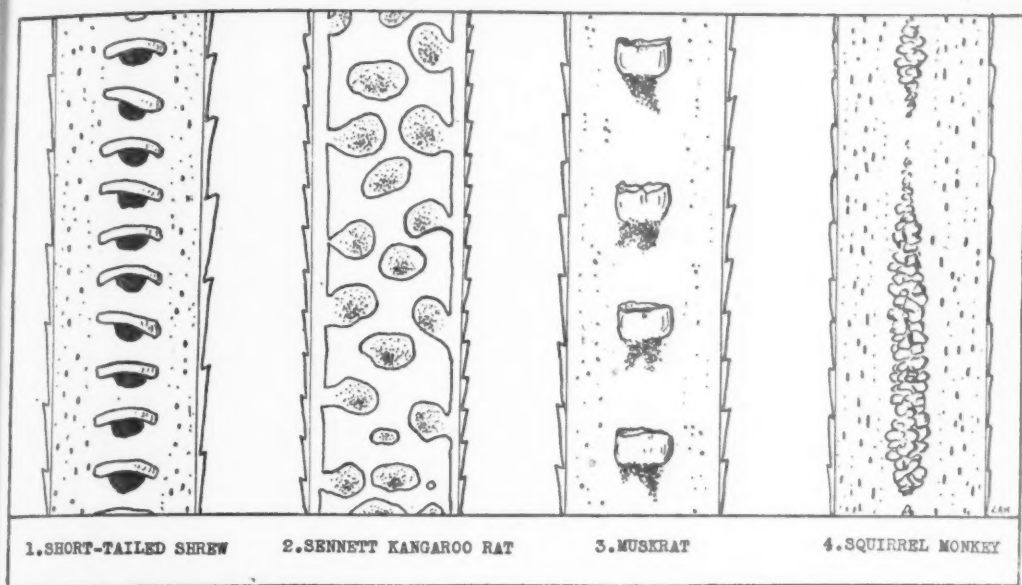


FIG. 2. FOUR HAIR-SHAFTS SHOW MARKED DIFFERENCES IN PIGMENTATION. THE HAIRS WERE SELECTED FOR THEIR NEARLY UNIFORM COLOR. THEY DIFFER IN DISTRIBUTION OF PIGMENT.

thumb and finger; if the base is free, one is conscious of resistance to the movement—of a sensation that might be called vibratory, caused, of course, by the unidirectional scales catching in the skin. The same conclusion may be drawn by simply rubbing a hair between thumb and forefinger; the base will always move away from the fingers.

The scales differ in form, size, and relationship in different animals, and in hairs of different diameters. They do not contain coloring matter in their natural state. Consequently, when the microscopist sees a hair-shaft with its scales colored, he knows that the hair has been dyed. This is often an important bit of information, especially if only a minute fragment of a hair-shaft is available for examination. The scales of some hairs are very delicate and easily injured by rough treatment. The microscope will show this. Or again the microscope will tell you whether you are looking at a hair from an otter, a beaver, or a rabbit—from the size and form of the scales. Notice the great variety of forms of cuticular scales of the hairs shown in Figure 3.

Sometimes the scales of the hair do not help the microscopist much in his analysis; he then turns to another element of the hair-shaft structure, the medulla, which is a sort

of "pith" running up through the center of the hair-shaft, and forming, as it were, a sort of core. It is not present in all hairs; the very finest, like those from bats, are without it. Wherever it is present, it forms an important part in the determination of the source of a hair sample, though alone and unrelated it cannot be used for this purpose. In human hair, especially, the kind of medulla which a hair-shaft possesses is correlated with the diameter of the hair-shaft; at least a correlation has been found in the study of 483 specimens of human head-hair taken from individuals ranging from three hours to ninety-one years of age. Medullas consist of masses of shrunken and tangled cells and assume many forms (Fig. 3). In this picture they are drawn as they appear through the microscope with the light thrown up through the hair-shafts from below. In some medullas there are masses of coloring substance arranged in characteristic patterns for the species of animal bearing the hair—a very important fact for the microscopist. The way in which light is reflected from the medullas of hairs in the mass gives certain sheens and colors to the hair.

Scales and medullas are the first structures that the microscopist studies, for these are the larger, more easily seen elements in the

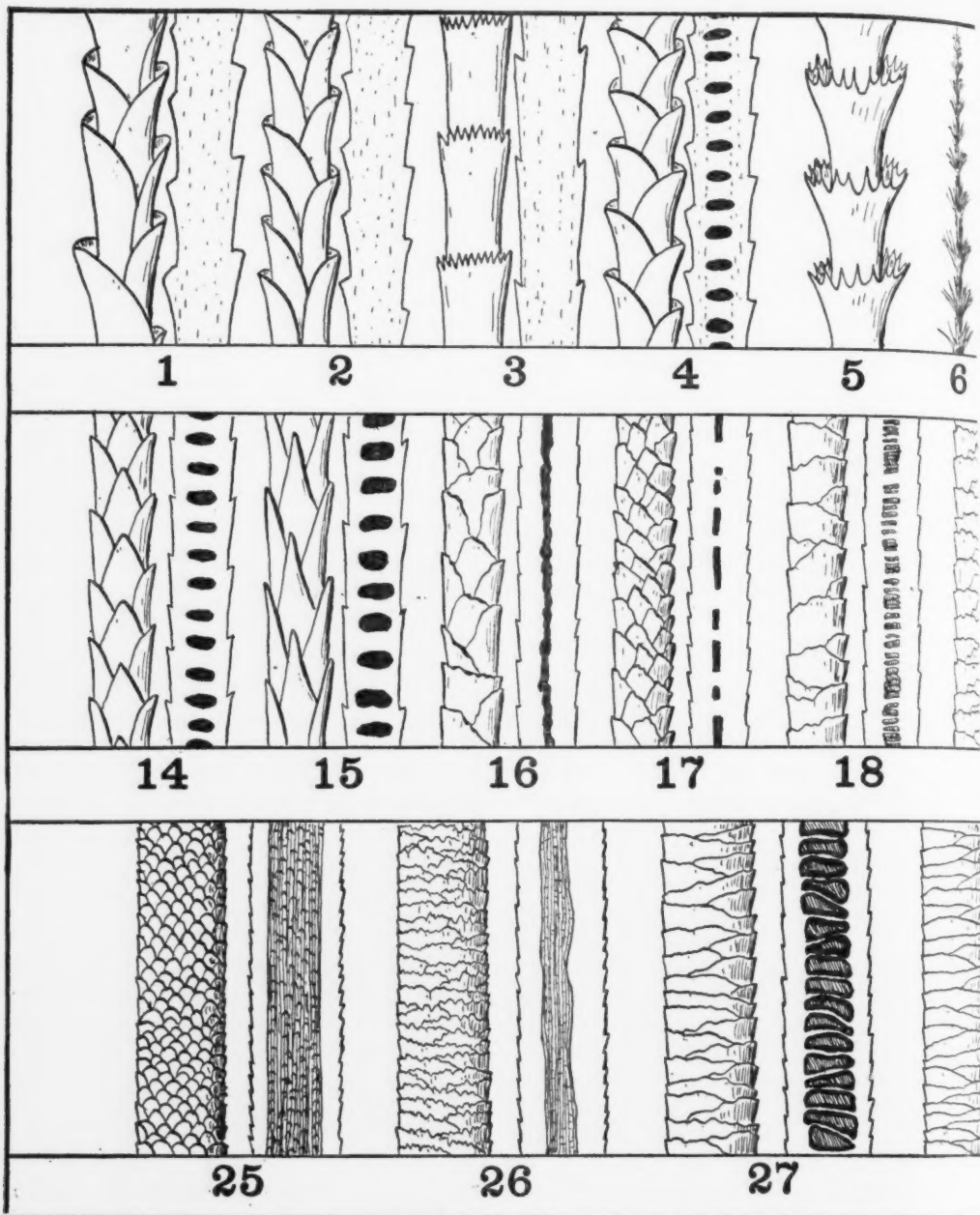


FIG. 3. REPRESENTATIVE HAIR-SHAFTS FROM VARIOUS MAMMALS. LEFT USUALLY THE MIDDLE PORTION OF THE FUR- OR UNDER-HAIR IS SHOWN. MAGNIFICATION VARIES; DIAMETERS

- |  |   |
|--|---|
| 1. Hammer-headed Bat ( <i>Eupomorphorus anurus</i> ) | 9. Pipistrelle ( <i>Pipistrellus subflavus</i> )  |
| 2. Spotted Bat                                       | 10. Brown Bat ( <i>Myotis lucifugus</i> )         |
| 3. Intermediate Bat ( <i>Mormoops intermedia</i> )   | 11. Mastiff Bat ( <i>Molossus sinaloae</i> )      |
| 4. Malay Vampire Bat                                 | 12. Civet ( <i>Arctogalidia fusca</i> )           |
| 5. Free-tailed Bat                                   | 13. Coypu, or Nutria ( <i>Myocastor coypus</i> )  |
| 6. Tip of hair of No. 5.                             | 14. European Mole ( <i>Talpa europea</i> )        |
| 7. Wrinkled-lipped Bat ( <i>Nyctinomus bocagei</i> ) | 15. Star-nosed Mole ( <i>Condylura cristata</i> ) |
| 8. Base of hair of No. 7                             | 16. Red Kangaroo ( <i>Macropus rufus</i> )        |

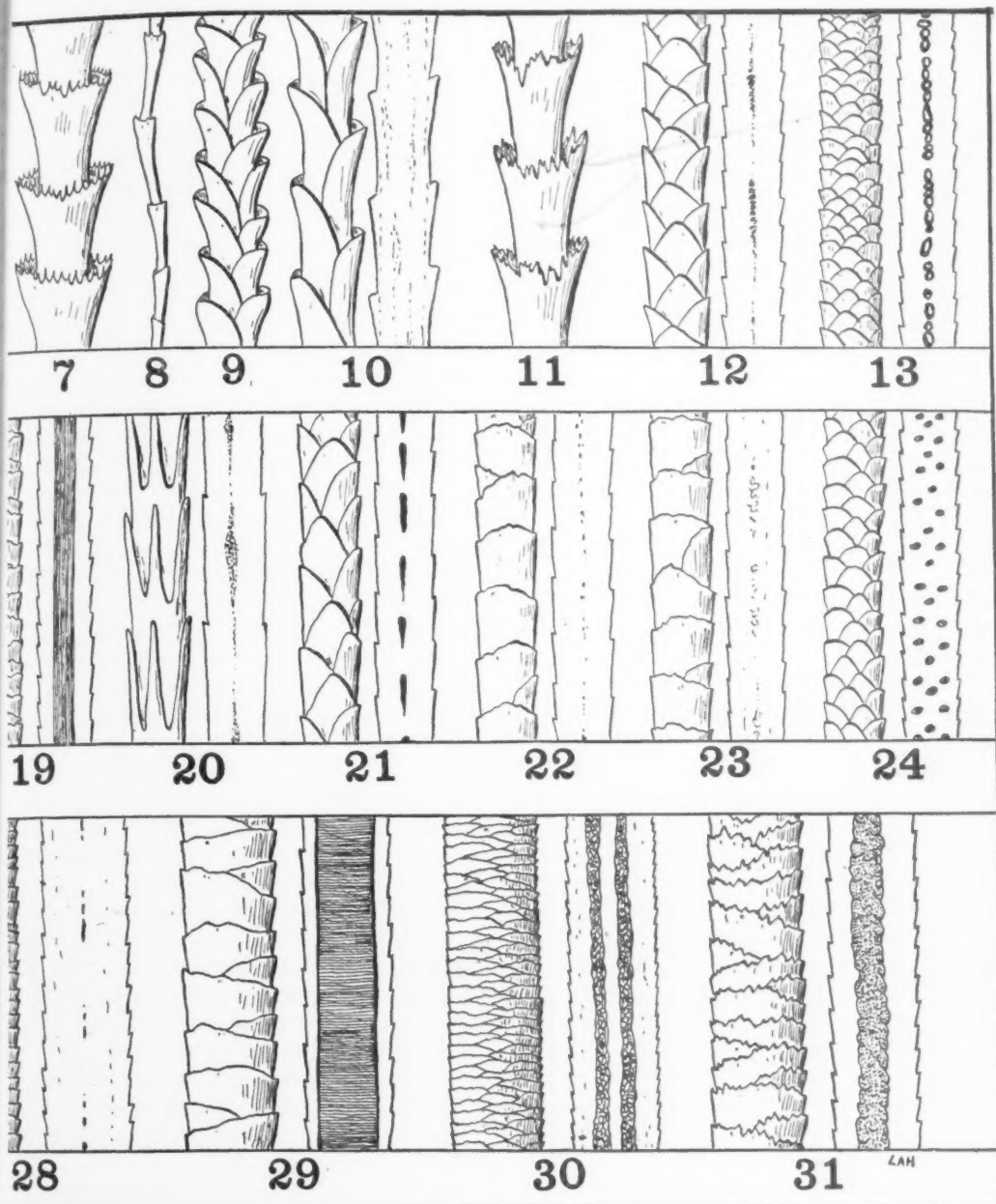


FIGURE OF PAIR SHOWS THE SCALES; RIGHT, THE MEDULLA, IF PRESENT  
OF HAIRS 1 TO 24 RANGE FROM 8 TO 30 MICRONS; THOSE OF HAIRS 25 TO 31, FROM 50 TO 150 MICRONS.

17. Aye Aye (*Chiromys madagascariensis*)
18. Bactrian Camel (*Camelus bactrianus*)
19. Gray Kangaroo (*Macropus giganteus*)
20. Otter (*Lutra vulgaris*)
21. Raccoon (*Procyon lotor*)
22. Vicuna (*Lama vicuna*)
23. Sheep wool (Merino)
24. Pocket Rat (*Dipodomys agilis*)

25. American Pronghorn (*Antilocapra americana*)
26. Percheron, mare
27. Sea Lion (*Zalophus californianus*)
28. Mammoth (*Elephas primigenius*)
29. Thompson's Gazelle (*Gazella thompsoni nasalis*)
30. Fossil Ground Sloth (*Nothotherium shastense*)
31. European Hedgehog (*Erinaceus europaeus*)

structure of the hair-shaft and require only moderate powers of magnification. However, it is not always the magnification that is the determining factor in the success of the study of minute objects, but the way in which the object under examination is illuminated. We may magnify an object to fifteen or sixteen hundred times its original size, but if our focus is not sharp and our lighting bad, we may as well use a pocket lens!

The bulk of most hair-shafts is not made up of scales and medulla but of an apparently solid, semitransparent rod composed of many elongated, closely compacted cells. This element of the structure of a hair is known as the cortex (Fig. 1). Scattered about within and among its component cells are minute round or oval granules of pigment substance, which chiefly give a hair its color. They are called pigment granules (Fig. 4). They are related in definite ways and are arranged in definite patterns according to the color of the hair-shaft. They are shown in all the illustrations except Figure 3. Notice the relationships of these granule patterns to the colors of human head-hair as shown in Figure 4. Hair pigments are not always in the cortex; sometimes, as previously mentioned, they are present as masses of different sizes in the medulla of the hair (Fig. 2). Hair pigments may also be present in the form of a clear, diffuse stain in the cortex. The cuticle, or substance of the scales, however, is uncolored. The microscope often tells much about even a minute fragment of hair from the size, shape, patterns, and numbers of its pigment granules or masses. Relatively high powers of the microscope are necessary for the study of the pigment granules of hairs.

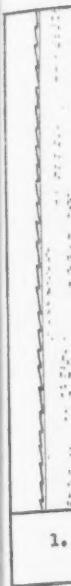
Among the structural elements of human head-hair, to which attention has been especially paid, are minute vesicles or chambers lying among the cells of the cortex of the shaft. Although well-known by various names to students of trichology, they had been neglected until 1932 when the writer began the study of these elements; first in a series of hair-shafts from some 200 species of animals, and then in a still larger series of human head-hairs. For aid in the collection and study of these specimens the writer

was indebted to the late Aleš Hrdlička of the United States National Museum in Washington and to Miss Elizabeth Wynkoop, then Instructor in Zoology in the N. J. College for Women, Rutgers University, and also to several of his students. The results of this first survey of the air-vesicles of hair-shafts was reported in a paper, "The Cortical Fusi of Mammalian Hair Shafts," in *The American Naturalist*, October, 1932, and the study of the series of 400 hair-shafts from human heads was reported in abstract at a meeting in December, 1934. With respect to the air vesicles of the hair-shaft it was then said that "unusual correlations sometimes encountered in hair-shafts, or modifications of the structure of the component elements may constitute individual variations, which, upon further study, may very well prove to have diagnostic value in aiding in the determination of hair specimens of problematical origin." This was also hinted at in the paper, "Histological Variability of Human Head-Hair" (*American Journal of Physical Anthropology*, March, 1934).

Inasmuch as the vesicles had been little studied, had been called by many different names, and were always cortical in occurrence and fusiform in appearance, the term *cortical fusi* was employed in the first paper, a term which has subsequently been adopted by other writers.

The relationships of these cortical fusi in the hair-shafts of the mammals below man is now being further investigated, but several cases of recent emergence in the writer's experience, in which it was necessary to endeavor to establish personal identification by means of hair-shaft examination, resulted in a special prior study of the status of these elements in the shafts of hairs from the human head.

In the human head-hair, as the proliferation of the hair-producing cells about the papilla pushes the young shaft upward through the neck of the follicle, the cortex cells are not at first long and fusiform, as in the mature hair-shaft, but are irregularly and elongatedly ovoid, drawing out into their characteristic spindle form as the shaft reaches, and emerges from, the mouth of the follicle. As this process continues, the cortical cells carry upward between them many



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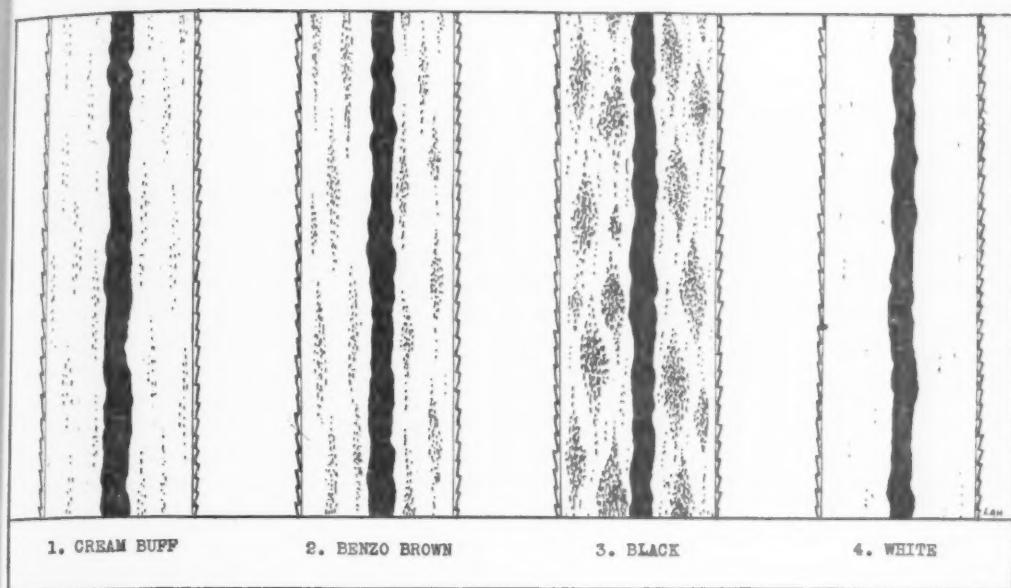


FIG. 4. TYPES OF PIGMENTATION IN HUMAN HEAD-HAIR

COLOR OF HUMAN HEAD-HAIR VARIES WITH THE NUMBER AND DISTRIBUTION OF CORTICAL PIGMENT-GRANULES. CREAM BUFF (RIDGWAY) IS A LIGHT YELLOWISH-BROWN, WHEREAS BENZO BROWN IS A MEDIUM BROWN.

elongated cavities filled with tissue fluid. These are usually most distinct in the hair-shaft just at, and above, the mouth of the follicle, a region termed the *formative region of the fusi*, although from a strict developmental standpoint their origin is just above the region of the hair-generative cells of the papilla. However, it is at the formative region of the fusi that they are first seen in their characteristic form. In most cases the fusi are intercellular, though some cortical cells may be observed in which the nucleus, having disintegrated, leaves behind an apparently hollow space, with dispersed granules similar to a fusus.

As the fusi are borne upward with the growing hair-shaft, their tissue fluid disappears, and they become compressed, thin, and are then distinguishable with transmitted light as delicate, fusiform dark streaks (Fig. 1). Only rarely are they of sufficient diameter, in the middle portion of the hair-shaft, to present the appearance of hollow chambers, except under the highest powers of the microscope.

The fusi differ, oftentimes in a rather constant way, in different parts of the same hair-shaft, and to some extent in hair-shafts from different parts of the same head, but they

bear their chief relation to the diameters of the hair-shafts in which they occur; as do also, in general, the forms of the cuticular scales and medullas. Very significant, and more helpful to the microscopist in search of the source of hairs of unknown origin, is the fact that these fusi are sometimes characteristic of the hairs in the head of a given individual; sometimes, indeed, so markedly different from others in respect to their form, size, disposition in the cortex, numbers, and the like, as to make them important to consider as elements of at least diagnostic aid where identification of the source is concerned. In this connection they are to be studied together with the other variable elements of the hair-shaft: the cuticular scales, medullas, pigment granules (and their patterns), and diffuse cortical stain. In some cases the fusi alone may serve for identification, as is strikingly true of so-called "ringed hair." To the naked eye ringed-hair appears to be banded like a fish line. The ringed appearance is caused by masses of fusi which occur at regular intervals in the shaft. Not many samples of this ringed, or banded, hair are on record. The sample in the writer's collection was kindly furnished by Dr. Eleanor McMullen of Wells College. In

some head-hairs examined in the writer's laboratory, the fusi were so unusually large and widely spaced as to constitute, it is believed, a trustworthy criterion for personal identification. In this case, hair-shafts from different regions of the same head all showed the presence of these unusual fusi. In some cases the fusi persist almost to the tips of the hair-shafts—another uncommon condition.

Not only do hair-shafts exhibit natural fusi, formed in the manner which has been described, but may also show rifts or ruptures between the keratized cortical cells of the mature hair-shaft, which differ in form from the natural fusi, and which have been termed *fracture fusi*. They make their appearance whenever the hair-shafts have been subjected to pressure sufficient to dissociate the cortical cells within a given region. Various hair-shafts respond variously to these pressures, some shafts showing fracture fusi upon merely the slightest pressure or light blow, whereas others develop fracture fusi only after much rougher treatment. Such fusi are not discoverable except upon microscopic examination of the shafts concerned. They are useful in aiding in determining the kind of usage to which the hair (or the head) had been subjected.

Natural fusi are sometimes difficult to distinguish from elongate cortical pigment granules or chains. In general, however, the fusi are drawn out into slender filamentous forms, and do not end bluntly as do most of the minuter and elongate pigment granules. In specific cases of hit-and-run automobile deaths fragments of human head-hair shafts, found on the fenders or other parts of the car, corresponded in their fusi with the head-hair shafts taken from the heads of the victims. Furthermore the numerous artificial or fracture fusi suggested, by their numbers, forms, sizes, and dispersal within the cortex of the shafts, the type of maltreatment sustained by the hairs at the time of their deposition on the surfaces where they were found. Subsequent studies have been made of artificial or fracture fusi produced in the laboratory in the cortex of hairs which had been subjected to experimental maltreatments.

These studies have lent further strength to the view that the fusi of hair-shafts—both natural and artificial—may become of in-

creasing importance in microscopy for personal identification and as appreciable aids in reconstructing in the mind of the investigator certain previous unwitnessed occurrences.

How is a hair-shaft prepared for microscopic examination? It is difficult to answer this question satisfactorily in a small space, for much depends upon what one is searching for. In general, the hair is washed thoroughly and repeatedly in ether-alcohol or in xylol to remove extraneous greasy matter, placed on a glass slip, covered with a very thin cover glass, and put at once on the stage of the microscope. This procedure will answer for the general examination of the cuticular scales, but much depends on the lighting of the hair and the magnifications used. If it is desired to study the medulla, the hair-shaft must be cleared by immersing it in some oil, such as oil of bergamont, or of paraffin, wintergreen, peppermint, or in xylol. The refractive index of the clearing medium should be about the same as that of the cortex substance of the hair-shaft under examination. If one wishes to study pigment granules and fusi, the highest powers of the microscope must be called into play.

It must not be supposed that one can take a hair-shaft, and, placing it under a microscope, make out all of its structures at one glance. With the higher powers of magnification all the parts of a hair-shaft (even a very fine one) cannot be seen at one focus, because the parts of a hair-shaft lie on and in a cylindrical structure. This is why it is so unsatisfactory to employ photomicrography in hair-study, except to give general impressions at low magnifications, or to call attention to some single element of structure at moderate magnifications. If one could take a moving picture of a hair while the focus of the microscope is travelling down through the hair-shaft cylinder from one side to the other, then one would have a record of what the eye of the microscopist sees as it travels down through the hair by means of the focusing screws of the microscope. Here is an opportunity for some photomicrographical motion-picture enthusiast to exercise his inventive capabilities.

# SCIENCE AND SOCIAL WISDOM

By SAMUEL BRODY

The tower of Babel was a part of a plan to penetrate Heaven . . . magnificent . . . but it ended in confusion.—WILLARD H. DOW.

SCIENTIFIC workers are becoming sensitized to the social implications of science, especially in relation to such new, massive social upheavals as global wars, and are wondering what fate may be awaiting humanity if the development and use of scientific war weapons should continue at the present rate. Many processes tend to correct such disturbances, illustrated by the development of ever larger federal groups such as the American United States, the British Commonwealth of Nations, the Russian Soviet Republics, and by the development of ever more extensive communications tending to unite the whole civilized world into one community. The following discussion attempts to formulate this problem of social disturbance and self-correction from the viewpoint of what may be called the theorem of Claude Bernard in biology, analogous to the theorem of Le Chatelier in physical chemistry. Both theorems are concerned with broad factors tending to restore disturbed equilibria, one in biologic, and the other in physical systems.

There are many categories and gradations in tendencies to restore biologic equilibria. One category is physiologic, designated by Cannon as homeostasis; also as wisdom of the body, or physiologic wisdom. Physiologic wisdom is normally automatic. Another category may be termed, by analogy, social homeostasis, or social wisdom, which ranges from the instinctive or automatic behavior level in bee hives to the partly purposive behavior in human societies. As will become evident from the following discussion, there are no sharp dividing lines between the various categories of tendencies to restore favorable biologic equilibria, and functionally, they all, normally, tend to promote the advantageous long-range survival of the individual or species. Advantageous long-range survival is the chief end of biologic wisdom, physiologic or social, auto-

matic or purposive. This is the functional meaning of social wisdom as used in the title of this essay.

The primary concern of this essay is social wisdom in human society, illustrated in particular by the development of science, moral values, religion, and art; all broadly defined from the biologic-evolutionary viewpoint. However, for purposes of general orientation, the first section is devoted largely to a discussion of physiologic homeostasis, or automatic physiologic wisdom, in the sense of Cannon.

The study of homeostasis is the analysis of the factors that maintain an advantageous dynamic steady state in a biologic (Cannon's physiologic) system in the face of conditions that oppose it.

Many examples may be cited to illustrate physiologic homeostasis, the best known of which is homeothermy, the maintenance of a constant body temperature in the face of wide fluctuations in the environmental temperature. The writer happens to be familiar with the temperature conditions in Miles City, Montana, where a government agricultural experiment station is maintained. The temperature there drops during the winter to  $-30^{\circ}\text{F}$ ; yet cattle, horses, and sheep winter outdoors without apparent harm. The annual environmental temperature fluctuation is  $130^{\circ}\text{F}$ , yet the rectal temperature of the horses, for example, wintering outdoors is constant, at  $100^{\circ}\text{F}$ ; the regulation is precise to within  $1^{\circ}\text{F}$ . How does the horse maintain such delicate temperature regulation?

It is generally known that the skin of sweating species, such as humans, is very cool in hot weather. This is because the vaporization of sweat involves great loss of heat, thus cooling the skin. The blood comes to the surface to be cooled by the skin and so the whole body is kept cool. This is the way sweating species as man, horse, mule, and ass keep cool in hot weather. Some slightly sweating species, such as dogs, keep

cool mostly by protruding the highly stretched tongue and panting, that is, blowing air at a rapid rate over the enlarged moist mucous-membrane surfaces, thereby accelerating the rate of water vaporization. Of course, there are other things that occur, or that the dog does, in hot weather to keep cool: the thyroid activity is depressed and therefore the oxidation rate is depressed; the dog keeps out of the direct sun; he refrains from exercising; he wades in pools or streams; he reduces his food intake, and so on. All this constitutes canine physiologic homeostasis or physiological wisdom as regards body temperature regulation in hot weather. Such nonsweating species as swine keep cool with the aid of mud wallows; the moisture from the mud vaporizes and, like vaporizing sweat, keeps the skin cool.

Quite incidentally, mules and asses appear to have higher hot-weather physiologic wisdom than horses because of differences in emotional patterns. The horse, intent on pleasing, may be stimulated to work in hot weather until he drops dead from "heat stroke"; the more independent, "stubborn," mule or ass cannot be so stimulated to overwork. This is the probable explanation of the reputation mules have of withstanding hot weather better than horses. For the same reason, colored folks are said to be able to withstand hot weather better than white folks: the ambitious white man can be stimulated to work in hot weather until he drops dead from heat stroke or heart attack, whereas the colored man, not troubled by white-man's ambitions, cannot be stimulated to overwork. This temperamental difference in humans may be genetic but is more probably socially conditioned.

On the approach of cold weather the horse develops cold-weather homeostatic mechanisms: he grows a highly insulating, shaggy coat of hair; he increases the thickness of the insulating fat under the skin; when the weather gets quite cold, the superficial blood vessels contract, driving the blood out from the skin, thereby rendering it insulating like a glove; his thyroid becomes more active, thereby accelerating the oxidation processes in the body; he consumes great quantities of "heating" feed (poor hay, relatively useless

for productive purposes, is excellent for keeping the animal warm because it has a high "dynamic effect," like a beefsteak in the human diet, which is excellent to keep one warm in a cold environment). The horse does other things to keep warm: he keeps out of the wind, seeks shelter, seeks the direct sun's rays; he resorts to social-temperature regulation by huddling together with other horses, and so on. The neuroendocrine system synchronizes the innumerable bodily temperature-regulating mechanisms with the outdoor temperature.

While the horse grows his winter coat of heavy hair, his master almost as automatically, but on a different mental level, puts on his sheepskin and other winter clothing to supplement the purely physiologic protections against cold.

Another well-known illustration of homeostasis relates to oxygen and acid level regulation. The process of living involves the consumption of enormous quantities of oxygen and production of equivalent quantities of acids (carbonic, sulfuric, phosphoric, uric, and so on). Yet the levels of oxygen and acid in the cellular environment remain constant even during exercise when the oxygen consumption and acid production may increase to twentyfold the resting level. This constancy of the intimate cellular environment in the face of environmental change is brought about by many mechanisms ranging from increasing the rates of ventilation and circulation to increasing the concentration of hemoglobin in blood. The hemoglobin may be increased by its liberation from the spleen and liver depots or, if there is time, by acclimatization mechanisms which not only increase the rate of hemoglobin production but also change the hemoglobin composition so that it can carry more oxygen per unit weight.

A less well-known illustration relates to the effect of hormone administration or hormone-gland removal. If thyroid hormone is administered to a normal animal, the animal may, nevertheless, maintain the normal metabolic level by depressing its own thyroxin production. If the sex hormone estrogen is injected, the animal nevertheless maintains a normal level of sex activity by re-

ducing the production of its own estrogen and by increasing the rate of its elimination.

When an animal is excited and ready for a fight, sugar is automatically (under the influence of the pituitary and adrenal glands) poured into the blood to furnish the energy for the forthcoming fight; if the fight does not materialize on a physical plane (as in the case of a spectator at a football game, who does not himself fight although emotionally geared thereto), the sugar is eliminated by the kidney, constituting the well-known phenomenon of emotional glycosuria, thus keeping the blood-sugar level constant.

A certain disease of the adrenal gland is associated with extreme loss of common salt; the animal automatically (under the influence of the taste-hunger mechanisms) compensates this salt loss by consuming enormous quantities of salt. Indeed, extreme salt consumption is often a diagnostic symptom of such adrenal disease. Similarly, removal of the parathyroid gland (which regulates calcium metabolism) is associated with a craving for, and fourfold consumption of, calcium, and conversely an unusual craving for bone or earth may indicate parathyroid abnormality. Appetite is, under natural conditions, frequently a good guide to nutritional wisdom. For instance, herbivorous animals, such as cattle and squirrels, do not normally consume animal products, yet they relish bones during gestation and lactation when there is an extra demand for calcium. The hunger mechanism is complemented by other devices. Thus heavy lactation with its high demand on the blood calcium enlarges the parathyroid gland to enable it to draw on the skeleton calcium, thus supplementing the dietary calcium.

A spectacular homeostatic example is furnished by the regeneration of limbs in lower animals (recall the experiment of removing the tail of a tadpole and watching the regeneration of the tail to its "normal" length) and in healing of wounds in higher animals. Some types of healing, as that of tongue or gum, occur in the course of minutes or hours, especially if one is young.

Incidentally, aging is associated with decline of homeostatic function; aging is, indeed, best measured not by the number of

years lived but by the ability to maintain constant the internal environment, such as the internal body temperature or the internal level of the oxygen, in the face of a rapidly changing corresponding factor in the environment. Chronic disease and death are associated with the results of failure of homeostatic function. The immediate cause of death is normally a breakdown of homeostatic function, inability to restore to normal a seriously disturbed condition; for example, the inability of healing a wound, inability to maintain body temperature constant (fever), or inability to overcome an infection. The system disintegrates, dies, if the homeostatic ability is lost; and what is true for an individual appears to be true of some animal societies.

The problem of physiologic homeostasis may, perhaps, be viewed from what has been termed the organismic, or field, theory in biology, similar in intent to the field theory in physics. Just as the field in physics may be conceived to be a physical (an electromagnetic) integrative process, so the field in biology may be conceived to be an integrative biologic process binding many components into a whole and tending to be restored on disturbance, which is one definition of homeostasis, the tendency to be restored to normal on disturbance. The organismic viewpoint leads to the inference that in the struggle for survival in the course of evolution the component parts of the body had to develop so as to function in symphonic harmony of an optimal pattern. An organism is a closely-knit community, the component members of which—nervous, endocrine, circulatory, excretory, digestive, and so on—co-operate in maintaining a dynamic steady state in the face of fluctuating external conditions. This is essentially Claude Bernard's generalization in modern language.

There is no sharp dividing line between physiologic and social, instinctively-automatic and conscious homeostasis, or wisdom.

For instance, the reproductive function attains peak activity when growth approaches its end, that is, when the individual organism begins to get old. The lawn grass goes to seed most readily when individual

life is threatened or is on the decline (as in drought, etc.). Reproduction of the individual may be viewed as a social homeostatic mechanism. By reproduction the "internal environment" of the social organism is kept constant in spite of the aging and dying of its constituent members. Incidentally, only human beings survive for long periods following cessation of the reproductive function; this may be an important condition for developing disinterested wisdom.

The reproductive process is extremely complex and, needless to say, the reproductive drive tends to be satisfied whether or not the individual animal foresees its sociocentric purpose; just as hunger and thirst drives are satisfied whether or not one foresees their ultimate aim. In either case the ultimate functional aim appears to be to maintain constant what Claude Bernard termed the internal environment of the organism, individual and social.

The homeostatic mechanisms tend to evolve to ever higher or finer organizational levels. For instance, the most evolved animals, the mammals, do not drop their eggs in the ocean as fish do, but house and nurture the young in an especially evolved body cavity, the uterus; then after birth the mother gradually bridges the young to the independent mature life by warming it, cleansing it, and feeding it with a special food, milk, elaborated by the mammary gland. The development of the mammary gland is synchronized with the development of the reproductive organs, and the activity of the gland in milk production is synchronized with the dietary needs of the young. This perfect synchronization is brought about by complex neuroendocrine mechanisms.

Incidentally, man learned to expand this natural lactation function in dairy cattle to unnaturally, fabulously high levels, for his own rather than the calves' benefit. Dairy cows have been developed to produce some fifty quarts of milk a day, every day for 365 days, completely out of the range of the need of a growing calf. This example illustrates the plasticity, adaptability, and potential range of homeostatic functions. The homeostatic function may be, so to speak, misled

or stimulated to act outside the range of biologic usefulness and indeed to the detriment or even destruction of the organism. This is an important biologic fact from our viewpoint.

Another example of adaptability and plasticity of homeostatic function relates to the time of sex mating. Species that evolved and are living in regions with wide seasonal temperature fluctuations confine their breeding activity to a sharply limited interval of the year. The time of breeding depends on the length of the gestation period; mating occurs only at such time of the year as will give the newborn animal the highest probability for survival. Shifting of the animal to another latitude changes correspondingly the breeding date. Shifting the animal to the tropics where fluctuations in temperature, light, and food-supply are insignificant, or domesticating it so that its food supply, warmth, and light are uniform throughout the year, often abolishes the seasonal breeding rhythm. Thus, whereas wild cattle breed in the autumn only, domesticated cattle breed throughout the year. Whereas wild fowls produce only one batch of perhaps a half dozen or dozen eggs in the spring, domestic fowls may produce eggs throughout the year, often 300 or even 365 eggs a year. The internal biological controlling mechanism of the seasonal breeding rhythm resides in the anterior pituitary body (at the base of the brain); the external controlling agent is usually sunlight (ratio of day to night length), and the external stimulus is usually carried to the internal control by way of the optic nerve (the eye). This mechanism is definite but plastic, modifiable, educable, so to speak, to act differently under changed conditions.

The intimacy of the mammalian type of reproduction develops family life. Family life is also strong in many birds, especially in those, like pigeons, which produce "crop milk," and on a different organizational level, in social insects. But it is perhaps on the highest level in mammals, and particularly in man, distinguished from other mammals by a higher level of consciousness and by raising children of different ages simultaneously, thus evolving a special type of

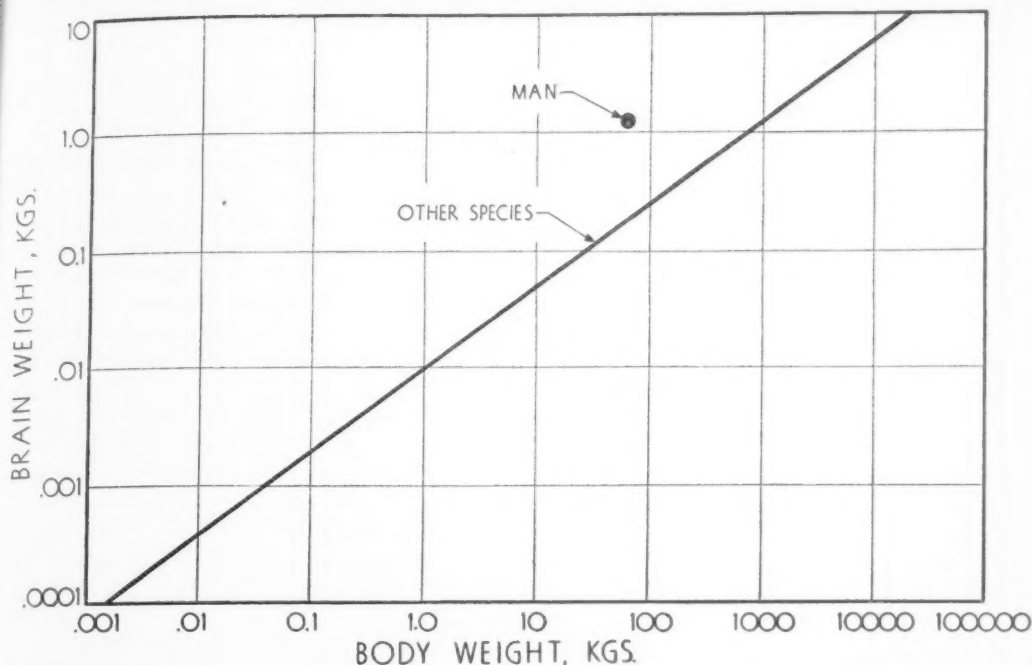


FIG. 1. RELATION OF BRAIN WEIGHT AND BODY WEIGHT IN MATURE MAMMALS. THE DIAGONAL LINE SHOWS HOW AVERAGE BRAIN WEIGHT OF NONANTHROPOID MAMMALS IS CORRELATED WITH THEIR AVERAGE BODY WEIGHT. THE AVERAGE WEIGHT OF MAN'S BRAIN (BLACK DOT) IS EXCEPTIONALLY HIGH.

social life between individuals of different age and strength and leading to the development of the uniquely human social characteristic of patience, forbearance, and charity on the part of the older and stronger children towards the younger and weaker. This is, perhaps, the biologic origin of morals, ethics, and religion.

In man we see the family idea, with its higher level of conscious regulation, or homeostasis, develop into ever larger aggregations—tribe, clan, nation, and ultimately, perhaps, supranation. These broader human aggregations are made possible by the unique human ability for abstract thinking and communication in symbolic terms—language. By such communication man learned to recognize, in an impersonal way, the relatedness of all men. These unique recognition qualities in man have a structural basis in his nervous system. Primitive animals and primitive functions in higher animals are controlled by the autonomic nervous system concerned primarily with adjustment between organs within the

individual; the higher functions in the more evolved animals are controlled by the central nervous system, especially by the brain and more particularly by the forebrain or the cerebral cortex, concerned with adjustment of the organism as a whole to distant environment. The development of the brain reached enormous proportions in man with correspondingly far-reaching recognition qualities. The brain weight (by no means the only index of high development) in 150-pound man is 3 pounds, whereas that in 150-pound sheep is only  $\frac{1}{4}$  pound and in 1500-pound cattle it is one pound (Fig. 1). Indeed, with the exception of whale and elephant, man has the largest brain of any species.

The above discussion indicates the presence of many categories of homeostasis or wisdom, ranging from automatic physiologic processes and, perhaps, completely automatic social behavior in some social insects, to the relatively unpredictable social behavior of higher birds and mammals and particularly

of man. The difference between these various categories is one of degree, that is, quantitative rather than qualitative. Man, for example, has the same physiologic functions and emotional drives as other mammals although his cerebral activities, his mental powers, function on a higher level.

These differences in level of mental activity and in predictability, of course, have important implications. Human behavior is relatively indeterminate and unpredictable, which makes it difficult to develop a science of human social behavior as it is possible to develop a science of physiological behavior or a science of insect social behavior. On the other hand, the relative unpredictability of human social behavior, which is the despair of the social scientist, offers man an opportunity to mold human behavior, and even to mold destiny, which is not given to other species; it gives a biologic basis to the biblical assertion that "The Kingdom of Heaven is within you," and it poses the problem of how to develop a social wisdom to translate this potentiality into reality.

Human social wisdom differs especially from subhuman wis-

dom in that human social behavior on the exclusively human level is conditioned by tradition, by an ever-growing body of experience. Let us define the elements of social wisdom on the uniquely human level—definitions that may indicate their functions.

The elements of social wisdom on the uniquely human level are, in the writer's opinion, objective knowledge of natural phenomena represented by science and the subjective attitude to the universe, especially to humanity, typified by religion and art.

Science and religion are interrelated in that both represent man's tendency to generalize what appear to be important phenomena. Our biblical cosmology may, from

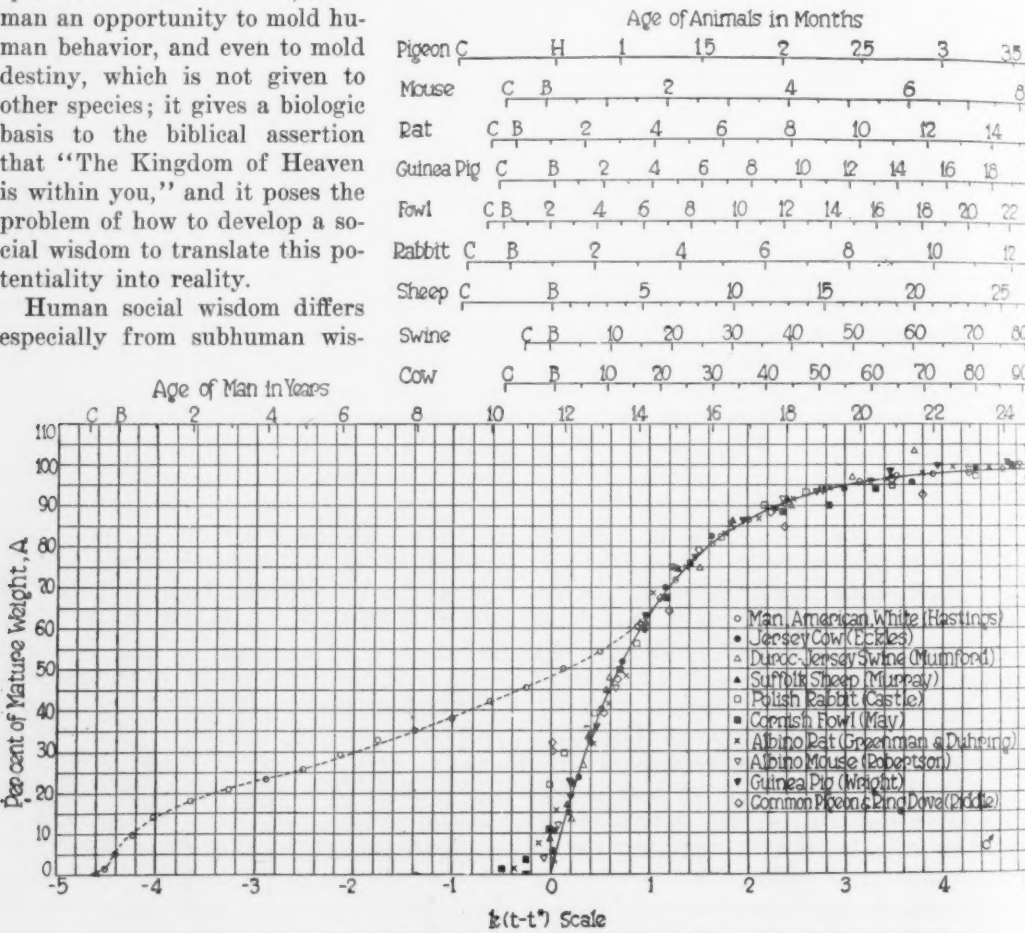


FIG. 2. AGE CURVES OF GROWTH IN WEIGHT IN MAN AND OTHER SPECIES ILLUSTRATING THE PECULIARLY SLOW GROWTH OF MAN. C = CONCEPTION, H = HATCHING, B = BIRTH.

this particular viewpoint, be considered to have been the science of the age when the Bible was written; and our modern cosmology may in turn be said to have evolved, in part, from our biblical cosmology. The fact that the biblical cosmology is outmoded is not a valid argument against this viewpoint since science is continually changing and some present theories, in the younger sciences at any rate, may in turn be outmoded.

Science and religion are also interrelated in that both have their biologic origin in the highly developed human brain (Fig. 1), in the peculiarly slow human growth rate (Fig. 2) (the prepubertal percentage growth rate of sheep and goats, which have the same mature weight as man, is sixtyfold that of man), in the relatively very long human life span (about sevenfold that of subhuman mammals of the same mature weight), and in the possession of the mechanisms of speech and writing.

The large and highly developed brain affords reflective power and furnishes the basis for speech and writing, the long growth period affords opportunity to learn, and the long life span affords time to reflect and to develop traditions, all of which are prerequisite for the development of religion and science. Moreover, the long human childhood period of dependency on parents stimulates socialization, the rearing of children of different ages simultaneously (a uniquely human characteristic) reinforces socialization with charity and tolerance on the part of the stronger to the weaker children, and the mental consciousness of the involved relationships lead to the development of group morals. This combination of circumstances was associated with the evolution of symbolic, abstract, and conceptual methods of thinking and transmitting knowledge, especially to successive generations, and consequently led to a new method of biologic evolution depending on social inheritance of knowledge rather than on changing the genetic constitution of man.

With this background in mind we proceed to define science, moral values, religion, and art, the elements of wisdom on the exclusively human level.

*Science* is concerned with the description

and logical organization of objective, independently verifiable observations. Scientific knowledge is photographically literal, emotionally and morally neutral, allowing only for relativity effects.

This definition represents only the objective and the amoral aspects of science. Science has other aspects, of course; it has high spiritual, moral, and aesthetic values also, as that of bringing out the beauty, the unity, the "wisdom," and the "moral order" of the universe. But from the viewpoint of social wisdom on a human level, it appears simplest to view science from the morally neutral viewpoint; and as such, scientific knowledge may be compared, for example, to morally neutral fire, which may be used for warming and cheering or for burning and hurting, and it is so used for both. For example, scientific knowledge has been employed to raise health, longevity, material comforts, intellectual and spiritual satisfactions (travel, radio communication and music, insights into laws of nature) to the highest level in history, and it has also been used to raise the destructive power of war and the social confusion to the highest level in history. Scientific knowledge is growing rapidly and so is its potentiality for construction and destruction.

*Moral values* may be considered from several functional or operational viewpoints.

From the religious viewpoint moral behavior is judged by its effects on human life. Jesus said, "By their fruit ye shall know them," and all great historic religions, that is, those that survived long periods, have the Golden Rule as a common element. This is indicated by the following quotations: Jesus said, "All things ye would that men should do unto you, even so do ye also unto them." Rabbi Hillel (Jesus' contemporary) said, "What is hateful unto thee do not do unto thy fellow." Plato (427-347 B. C.) said, "It is worse to inflict wrong than to suffer it." Confucius (551-478 B. C.) said, "What you do not want done to yourself, do not do unto others." An Egyptian code of 5300 years ago states: "Life is given to the peaceful and death to the criminal." Recently F. R. Moulton proposed a code of international ethics on the same

principle: "Each of the signatories hereto agrees to ask for and accept from the other contracting party only such privileges, rights, and commitments as it will offer to the other party."

The Golden Rule appears to have a sound evolutionary-biological basis because, as S. J. Holmes remarked, although people ascribe the origin of their codes to the commands of their gods, the true cause for their development is their survival value.

From the Darwinian or evolutionary-biologic viewpoint, the criterion of "moral behavior" is advantageous long-range survival of the species. Moral behavior is thus socially beneficial behavior, and moral values are socially beneficial values.

We have already defined social wisdom or social homeostasis as behavioral reactions which promote social survival. It is thus evident that while moral values, social homeostasis, and religion are not identical concepts, they are functionally related; they are all concerned with the advantageous long-range survival of man. Advantageous long-range survival is the criterion of wisdom, physiologic or social, automatic or purposive.

There are those, like Arthur Schopenhauer, who deny, on philosophic grounds, the desirability of the survival of man but, as aforementioned, this discussion is from the evolutionary-biological viewpoint only.

*Religion* is more intricate than science or moral values because religion is the parent of science and moral values and of many other concepts, real and imaginary, mental and emotional, and traditional religion is, therefore, cluttered with many vestigial parts, meaningful in the past but confusing and troublesome in the present.

Present-day religion, as conceived by the writer, is concerned not with cosmology or science as such but with the purpose for which scientific knowledge should be used, with the attitude of man to mankind and the universe. As aforementioned, the great historic religions have the Golden Rule as their moral basis, and while not always easy to interpret under practical conditions, this seems to be the best available guide for the moral conduct of life if judged by functional criteria "by their fruit ye shall know them." So

much for the moral aspect of religion, which has a high social-wisdom value.

From the other, spiritual, viewpoint religion is a groping for integrated living, for a unified life purpose, for "the chief end of man"; it is a philosophy of the meaning of life, its frustrations, tragedies, and spiritual experiences, usually involving communion with a "supreme reality."

The nature of the spiritual reality, deity, or divinity is not, however, generally accepted as is a given scientific reality, but varies among groups and individuals ranging from an anthropomorphic entity extending the gift of eternal salvation to his devoted worshippers and the "punishment of eternal damnation for the sinners" (Jonathan Edwards) to an abstraction expressed in various ways: a poetic mystic spirit; "God as the incarnation of the moral ideal of mankind, the perfection for which man strives" (J. W. Hudson); a consecrated value; a "Devout and Contented Uncertainty" (Roger Williams); the recognition of the "Seed of Divinity in Every Human Breast" (William Ellery Channing); "The Personification of All That Is Best" (W. C. Allee); the sacredness of scientific progress in promoting human welfare, or "Scientific Humanism" (J. Huxley); the "Contemplation of the Beauty of Holiness" (A. N. Whitehead), and so on.

From many viewpoints religious revelations, attitudes, and realities are analogous to, if not identical with, certain artistic revelations and realities; the exaltation or spiritual satisfaction derived from the contemplation of the sacred seems, however, to transcend for most individuals those derived from the contemplation of the secular (art, science, nature). However, a slight change in view or in conditioning of attitude may transfigure the secular into sacred. Thus the practice of the Golden Rule could be transformed into sacred ritual.

An important aspect of institutionalized or conventional religious creeds and rituals is that they are rarely accepted by adults who were not conditioned to them in childhood, and a child can be conditioned with equal ease to any religious faith. This is the basis of religious and sectarian quarrels,

a potent cause of irrational friction and even war. This is an important difference between religious beliefs and scientific knowledge: whereas the scientific law of gravitation, for example, is generally accepted, a given religious doctrine or ritual is usually accepted only by those conditioned or indoctrinated in childhood. Hence one speaks of scientific knowledge but of religious creed, doctrine, or feeling, which vary with individual vision, environment, and background.

As aforementioned, the biologic-evolutionary, including the homeostatic, viewpoint is concerned with advantageous long-range survival of the species. This preoccupation with the advantageous long-range survival of the species may, figuratively, be designated as the biologic religion or moral code. But religion likewise appears to be preoccupied with the advantageous survival of humanity. This is indicated not only by the religious tradition of immortality but especially and much more significantly by the recognition of ever wider human kinship, as indicated, for example, by the Christian-Hebraic monotheistic doctrine of one God, one Father, and the brotherhood of man. Biologic, including homeostatic, and religious aims thus appear to converge, indeed to coincide, at their limits. Religion, indeed, appears to be a biologic-homeostatic phenomenon. A biologist may, therefore, define religion to include both the biologic and the limiting traditional-religious viewpoints, thus: *Religion is the consecrated devotion to the values and/or to the faiths (that may or may not be mystic and/or theistic) which seem to promote the best interests of humanity.*

This definition or interpretation of religion has many practical implications.

First, this definition eliminates the so-called conflict between science and religion. Religion is represented as an attitude promoting the advantageous long-range survival of humanity, and leaves to the individual whether or not this attitude should be mystic and/or theistic in spirit.

Second, this definition of religion based on the Golden Rule and on the devotion to values which seem to promote the best interest of humanity is, so to speak, Basic

Religion, a common element possessed jointly by all healthy religions. The wide appreciation that Basic Religion as above defined is a common element possessed jointly by all healthy religions should eliminate the confusion, social friction, international misunderstandings, and wars associated with the attitude of those who regard other groups as heathen or pagan.

Third, the above interpretation of religion as including all of humanity is definitely opposed to the rationalization of racial wars, riots, and persecutions. While there are extremely wide individual and family differences within every living group (no two leaves on the same tree have precisely the same structural pattern), the most eminent biologists and anthropologists free from prejudicial conditioning and from the influence of pressure groups doubt the existence of biologic and/or humanly essential differences due to race as such, at least among the civilized peoples. Social and other environmental conditioning appear to exert a much greater effect on the behavior of the average member of a racial group than his genetically racial constitution. Quoting Redfield, "Race is a variable that depends upon custom and changes with historical event. It is not the actual but the believed-in difference of race that is of consequence and is darkened by propaganda. Political and sectarian movements seize upon racial issues for their power to align men against each other."

Race persecutions, that is persecution of minorities, may be an expression of a primitive animal drive for self-aggrandizement by persecuting the defenseless, as indicated by W. C. Allee's studies on the "pecking order" in chickens, mice, and other animal societies; and/or expressions of escape rationalizations, shifting of responsibility for one's frustrations, which is another form of self-aggrandizement.

The race problem which needs clarification on scientific and educational levels does not offer complications on the religious and moral levels.

Normally the biological reaction to an unfavorable factor is to overcome it by some

device, as by sweating in hot weather or by developing warm covering in cold weather. Some reactions, however, tend to run in a vicious circle. For instance, in unchecked fever the higher the temperature, the higher the rate of oxidation or heat production (law of van't Hoff and Arrhenius), and the higher the rate of heat production, the higher the body temperature. This is also the effect of external high temperature on non-sweating species, such as swine, that have no access to cooling devices such as mud wallows. The course tends to run in a vicious circle terminating in death of the individual from overheating.

There are probably similar vicious-circle phenomena in evolution. For instance, large size is a favorable factor for the survival of a young animal competing with its litter mates for food. Large body size may also be a favorable factor for a polygamous animal in his competition for a female. The result is that successive generations may inherit ever larger body size, with the ultimate development of races of giants, such as dinosaurs. The giant body size, however, probably led to the extinction of the species because large size is an unfavorable factor in search for food and in withstanding high temperature.

Sharp teeth are normally advantageous to predaceous species, such as tigers, and sharpness of teeth may run in a vicious circle. The saber-toothed tiger was so successful in developing his hunting teeth that he became the dominant species. But after obtaining this position of dominance for the species, the teeth were probably employed for improving dominance of individuals within the species. In this way the individuals with the most formidable saber-teeth alone succeeded in reproducing themselves, and this tendency assumed a vicious circle: the development of ever more and more formidable teeth could not be stopped, and the fighting became ever more dangerous, which may have led to extinction of the species.

The precise factors that led to the extinction of the saber-toothed tiger cannot, of course, be scientifically determined, since they occurred in ages past. But the above explanation, based on the appearance of

fossil specimens locked by their saber teeth, seems reasonable and illustrates in dramatic manner how seeming success may hold the seed of failure. The earth's layers are replete with fossils of highly evolved species which rose to prominence and declined to extinction. Even the brief era of written history, five or six thousand years, witnessed the rise and decline of human civilizations and animal societies, and some of the declines may have been caused by some such vicious-circle phenomena as were assumed for the saber-toothed tiger or for the dinosaur.

The story of the saber-toothed tiger recalls the contemporary crisis in the evolution of humanity. Man appears to be a social fighting animal who began his fighting career with his limbs, then developed the intricate technique of throwing missiles, such as stones, then shooting arrows, using swords and armor, then bullets. The effects of such warfare were relatively local although these small developments managed virtually to wipe out civilizations and probably, by killing off many physically able, to reduce the stature of many peoples, as that of the French by the Napoleonic wars.

But now, with the growth of science and technology, we no longer think of arrows or bullets and local wars, but of blockbusters, rocket guns, and of global wars, destroying and incapacitating millions of persons and wiping out untold material and cultural wealth. We also learned how to use words as war weapons in deadly psychologic warfare to frustrate and to stir up hates and fears on ever wider scales. The question naturally comes to mind whether fighting man will follow the path of the saber-toothed tiger towards extinction as the result of overdeveloped weapons? Will war casualties rise in geometric progression (30 million in World War I, 60 million in War II, 120 million in War III, etc.) until the species will have become incapacitated? Will our tower of Babel lead to confusion and exhaustion?

The above question brings into sharp relief the central problem of this essay; namely, the nature of the social homeostatic or

social-wisdom mechanisms of the species *Homo sapiens*, modern man, known in his present physical form at least 50,000 years. Has he now entered the vicious-circle era? If so, will the fact that man operates on a high level of consciousness enable him to redress or break up in a conscious, purposive manner this vicious-circle type of development? Will social scientists discover methods for aiding the social-wisdom forces in healing the ailing human society in its present evolutionary crisis as medical scientists discovered methods for aiding the physiologic-wisdom forces in healing an ailing body in its life crisis?

Man appears to be a social-fighting animal. As pointed out by Allee, Gerard, and others, the evolution of social-fighting animals involves a balance between two opposing yet interrelated drives: a) egocentric or egoistic, exemplified by the struggle for self-aggrandizement, for a dominating position in the social hierarchy; b) sociocentric or altruistic, exemplified by loyalty to the family, flock, herd, pack, or in man to family, gang, tribe, clan, nation, and perhaps eventually to humanity. There is no sharp dividing line between the two. Thus in human society individual development is egocentric yet socially beneficial, and indeed such concepts as democracy, *laissez-faire*, and Christian salvation stress individual development in the interest of society. War itself involves both of these drives.

Examples of human sociocentric drives were illustrated especially by the human method of rearing children of different ages and strength simultaneously, by man's various categories of loyalties and by the definitions of religion and moral values. One might also add to the sociocentric humanizing forces a new one, the influence of modern science, which operates disinterestedly on a world-wide basis.

For illustrations of the egocentric drive, it is sufficient to note that man hunts other species and even other human "races" for the sheer pleasure of the hunt, insensitive to and, judging by recent war atrocities, perhaps pleased by the pains he inflicts; he wars with other groups within his race and quarrels and fights with members of his own

group. Man has a good brain, uses it for devising ever more destructive weapons, although being rational and noble, he devises plausible, justifying reasons for irrational and ignoble fighting. Man invents and commercializes methods for blowing human beings to bits and uses the profits therefrom for building hospitals. Man has developed an extraordinary genius for getting himself into unnecessary trouble under the influence of the two opposing drives.

Paralleling and counteracting the development of man's increasing destructive powers which have been used to aid his pugnacious and self-aggrandizement drives, there has also evolved, in virtually all human cultures and under all conditions, a unique altruistic and integrative power, religion, with its basic elements of humility (the consciousness of a higher power than man, however defined) counteracting the pugnacious and self-aggrandizement drives, and "goodness" (illustrated by the Christian-Hebraic doctrine of human brotherhood and the Golden Rule) counteracting the wolfish fighting drives.

Thus viewed, religion, in a broad sense, acted as a stabilizing, social-homeostatic, social-wisdom, or social-survival influence in the face of developing combative weapons.

But the stabilizing or homeostatic function of evolutionary or traditional religion couched in the anthropomorphie and supernatural terminology of another day is weakening under present conditions.

While, as here defined, there is no conflict between modern science and religion—one is concerned with objective knowledge, the other with an attitude towards mankind and the universe—institutional, traditional religion does contain much that is irrelevant, and the questioning, critical, analytic spirit of science, which insists on ever more concrete evidence, tends to erode the authoritarian and irrelevant doctrines and ritual. Moreover, the encounter of contradictory religious opinions and practices, as a result of the development of rapid communication, urbanization, and migration which commingles persons of widely different religious viewpoints, blurs old religious traditions. The decline of traditions, the social-evolu-

tionary *moral carriers*, weakens the influence of the interrelated traditional *moral values*, thus tending to remove the inhibitions to the egocentric drives. The situation is, moreover, complicated by radical technologic innovations which led to technological unemployment and destitution in the midst of potential plenty with consequent frustration and irrational class, race, national, and other escape hates and strife, and finally to global wars.

The developments of science and technology, good in themselves, thus seem to have upset social-evolutionary equilibria between the egocentric and sociocentric forces, the balance between the power conferred by amoral knowledge on one hand and by the social-evolutionary, social-wisdom, or moral carriers on the other. Moreover, the greater the power of the amoral technological knowledge, the more dangerous it becomes if its use is not guided by social wisdom.

The result of the disharmony between the older religious or social-wisdom formulations and the new scientific-technologic age may be illustrated by the rise of the new German ideology. The apparent enthusiasm for it, as it appeared to the author during a sojourn in Germany in 1931, was in no small part due to a growing spiritual need for an integrating faith. This need was capitalized by little men making big promises in pseudo-scientific and pseudoreligious language. Men must have an integrating faith, and having lost their traditional deity and theology, they developed a new one, one that appears to lead to the vicious-circle pattern of evolution.

A major social-homeostatic need, then, seems to be to bring together science (organized factual knowledge, which is morally neutral) and religion and moral values in the sense of social wisdom as here defined. Since religionists do not appear to be able to

bring about this situation, it would seem that scientists, who now appear to command greater confidence and prestige than professional religionists or statesmen, and who are, in a sense, responsible for the disturbed evolutionary equilibrium between the effects of sociocentric and egocentric drives, should assume indirect social and religious leadership in this critical situation in promoting progress in creative religion (broadly defined as social wisdom) so that it will parallel the progress in creative science.

It is suggested that the representative bodies of scientists attempt to define and predict in scientific spirit and in simple language (perhaps by forums, symposia, and popular books on social wisdom) the ideals and the evolutionary trends of *Homo sapiens* and suggest strategy for avoiding perils, especially of the vicious-circle type, and for attaining the seemingly ideal objectives. Special attention should be given to defining and placing the problem and applications of religion on a universal basis, emphasizing the social-wisdom (in contrast to supernatural) functions of religion and thus minimizing religious and denominational frictions and wars. Social technologists, especially practical religious leaders, should similarly, in co-operation with psychologists, attempt to devise religious ritual on broad principles common to all historic religions, and based on scientific knowledge, for attaining the state that we think ought to be. The preparation of a compact social-wisdom guide or code and its annual revision in the light of new developments (so as to avoid fixation of the guide into a creed or dogma) with the accompanying publicity, may contribute greatly toward helping mankind to clarify the meaning of life and to avoid catastrophe. There could then be said of science what Jesus said of Moses' Laws: "I came not to destroy the Law but to fulfill it."

# BIOTREPY—THE GOOSE OF THE GOLDEN EGGS

By PAUL D. LAMSON

AFTER a cycle of some seven thousand years we are back where we started. We believe once more in "drugs." Everyone is scrambling for these golden eggs but there is a great difference of opinion as to what breed of goose lays them. The pharmacologist, the chemist, the pharmacist, those in various branches of industry and government, and more than a few in woodsheds and kitchens are convinced that they can conjure up eggs of gold. That these eggs are of pure gold, there is no longer any doubt. Even the patient can testify to this with a clear conscience and without bribery. Drugs are not used in therapy alone; investigators in all branches of medicine, whether anatomists, physiologists, biochemists, pathologists, or clinicians, know that chemical substances are often the best tools for their experimental work. The search for these golden eggs is therefore a problem of interest to all in medicine, chemistry, and industry, and to the general public as well. In the present rush for these magical eggs the goose that lays them has been sadly overlooked and almost no thought paid to the raising of goslings. We would do well not to repeat the error of the past and kill the goose. It is the object of this article to point out that a special breed is necessary for the laying of such eggs.

This article is not written, however, for the purpose of singing the praises of pharmacology, which has been a useful stepping stone in medical progress, but to suggest that it be replaced by a medical discipline better suited to our needs.

We seem to have overlooked the fact that the study of drugs is chemistry, which is not a biological subject. The "action" of drugs is still chemistry as the only action a drug can have is due to its chemical and physical properties. Its primary "action" in the body is chemical or physical but, except in rare instances, we cannot discover what this is. We have no idea what the chemical reactions of strychnine or morphine in the body are. We do know in certain cases, as that of sodium oxalate, that this substance reacts

with the calcium of the blood and forms insoluble calcium oxalate. There is nothing peculiar in this "action" of sodium oxalate in the body; it is exactly the same there as elsewhere. If we could tell the chemist with what substance in the organism strychnine reacts, he would be able to tell us in all likelihood what the reaction would be; he may even know this reaction now. But knowing either of these reactions does not tell those who do not understand the organism that sodium oxalate will prevent blood from clotting, that morphine will make the pupils constrict, a dog vomit, a Fiji Islander go wild, and a white man go to sleep. These are not "actions" of morphine; they are "reactions" of the organism. They are all physiological reactions secondary to the primary chemical one between chemical substances in the tissues and the "drug" introduced.

In medicine we are studying the human organism, a branch of biology. We study this organism as the chemist does his chemical substances; that is, by means of its *reactions*. The days of studying the organism in a static condition are passed. Gross and microscopic studies of the normal and pathological organism are fairly well completed and much has been accomplished in the chemical analysis of tissues. Now everyone is studying the reaction of the organism to stimuli of different sorts. Electricity and disease have been the two great classes of stimuli most used in the past. It is only more or less recently that we have come to realize the opportunities that we have for studying the organism by means of its reaction to chemical substances. Here we have almost a million tools. We can choose one to fit our needs and reshape it as a locksmith would a key. There is practically no limit to the tools that we might make. Through such studies we shall not only learn more about the functions of the body, but we shall obtain the means of bringing about desired reactions in disease.

I have suggested in previous publications that we give up pharmacology—which after

all is pharmacy, even in name—and replace it in our schools of medicine by a biological science which would emphasize *the study of the reaction of the organism to chemical substances rather than of the drugs themselves*. Let us consider why such a suggestion is made. It is not done simply to upset a well-established medical discipline, as it will be shown that pharmacology as such is not well established. The study of drugs in medicine has been a bone of contention for generations. First, under the heading of pharmacy, everything imaginable was given to patients without previous trial in animals. Over several thousand years many useful drugs were found by this method of trial and error, but such a high percentage of these substances were of no value that a period of therapeutic nihilism set in. For a long time there was no special group studying drugs in our schools of medicine. A great mass of facts and fancy was taught under the heading of "materia medica" by anyone willing to undertake the task. In 1850, Rudolf Bucheim, a great scholar and a good chemist, physiologist, and clinician, attempted to bring order out of the then-existing chaos by studying the "action of drugs" in animals, discarding the useless ones and arranging the others systematically according to their chemical nature. For this medical discipline he used the name pharmacology, an old synonym for pharmacy, but the failure of this plan can be seen in a single illustration taken from Bucheim's book. Under the heading, "Sodium Sulphate," a heterogeneous group of chemical substances were brought together:

- VIII. *Gruppe des Glaubersalzes*  
*Glaubersalz*  
*Bittersalz*  
*Schwefelsaures Kalium*  
*Phosphorsaures Natrium*  
*Weinsaures Kalium*  
*Seignettesalz*  
*Abfuhrendes Brausepulver*  
*Boraxweinstein*  
*Aethylschwefelsaures Natrium*  
*Doppelt kohlensaures Magnesium*  
*Citronensaures Magnesium*  
*Mannit, Manna, Mannasyrup*

The only reason for their being put in such a group was that these substances had the

common biological property of causing the body to react by catharsis.

A strictly chemical arrangement of drugs is of no value to a medical man, as can be seen if one takes any list of chemical substances, as the alphabetical one in the index of Dyson's, *The Chemistry of Chemotherapy*. No one can use such a list for medical purposes unless he already knows what he goes to the list to find.

- $\alpha$ :  $\alpha'$ -Dichloroisopropyl alcohol carbamic ester  
 3: 5-Dichlorophenyl arsonic acid  
 3: 8-Diethoxy-9-carboxylic acid  
 Diethylacetamide  
 Diethylaminoacetonitrile  
 Diethylaminolaetic nitrile  
 Diethylaminolaetic nitrile methyl iodide  
 Diethylaminophenylacetoneitrile

The tables of contents of a series of textbooks in pharmacology show how headings have changed from Bucheim's chemical headings to biological ones, but as yet there is no system or order.

If one studies the reaction of the organism to chemical substances, the critics will say that this is physiology, biochemistry, or pathology, and so it is, but all of us in medicine are doing the same thing and are separated into disciplines merely for the sake of convenience and specialization.

A very practical reason for giving up pharmacology and substituting a different medical discipline is that one cannot become an expert in pharmacology or specialize in any branch of it. One cannot become an expert on a million substances, and one cannot specialize because the study of a single drug involves the reaction of all of the thousands of parts of the organism, and even the most closely related chemical substances may produce utterly different bodily reactions.

If we reverse this and study the body as all others in medicine are doing, we can become experts—specialists on the nervous system, blood, or parasites—but experts of a different sort than those in any other field of medicine.

Space will not allow a discussion of the organization of such a medical discipline, which has been gone into elsewhere, but it might be pointed out that the reaction of the whole organism is the resultant of reactions

of its countless parts. To bring order into such a bewildering system I have suggested that the problem might be approached by systematizing our knowledge around the smallest biological unit of which the body is made, the cell. By studying and classifying reactions under types of tissue, regardless of their location in the body, it would make it possible to orient ourselves readily, as all reactions, no matter how complex, originate in certain cell types. As we are unable to discover exactly what cell types are affected in the greater number of reactions, we shall still have to arrange material under more general headings, but in all cases they will be of a biological rather than a chemical nature, except where we are dealing with single chemical substances within the organism.

A study of the evolution of medicine indicates that a split occurred early between biological and nonbiological subjects. It would seem time to take the last step and rid medicine of the single surviving branch which studies something other than the organism; namely, pharmacology. It is common knowledge that a change of name does not change the content of a subject. Giving pharmacy the name "pharmacology" did not change matters, and, except for a brief period in which it was thought something new was being done in studying the "action of drugs," the same dissatisfaction has followed pharmacology as that which followed pharmacy and "materia medica" in our schools of medicine, whereas no dissatisfaction has ever been found with pharmacy as such.

I suggest a new medical discipline and, consequently, a new name. I have coined a word for it, "biotropy," or more correctly, "chemobiotropy," from *bios*, life, and *tropo*, to change. Almost any name would do, however, provided it has a biological rather than a chemical connotation.

It is simple enough to outline a department of biotropy on paper, but quite a different matter to put it into operation. This could be done with a proper plan together with sufficient financial support, but such cannot be expected without proof of the value of the plan.

Pharmacology was started by Bucheim in his own house with his own money and later

was taken over by the University of Dorpat. Growth was very rapid as Schmiedeberg, Bucheim's pupil, was given a great institute at Strassburg from which the heads of nearly fifty pharmacological departments came. For a time this supposedly new field created great interest, which, however, gradually subsided. An analysis of what was done about pharmacology during the period of medical expansion in the twenties will substantiate this view, as will the opinion voiced at that time by Dr. C. W. Edmunds, then President of the Society for Pharmacology and Experimental Therapeutics. To the pharmacologist, the attitude of the medical profession towards "drugs" would have been exasperating if it had not been so naïve. The surgeon could not have operated without "drugs" (general and local anesthetics) and, except for what nature was willing to contribute towards a cure, the medical man relieved his patients by means of drugs only—morphine, cathartics, cardiac and vasomotor drugs, central nervous depressants, anti-syphilitics, antimalarials, anthelmintics, and a host of other substances. These were so commonly used that they were forgotten. Now we have the sulfonamides and penicillin. It is difficult to imagine another lapse of interest in drugs, but when one can disregard those mentioned above, he is capable of anything, and once more it may become the fashion to deery therapy and specialize on diagnosis and the autopsy. Those who have spent their lives studying the fascinating reactions of the organism to chemical substances are apt to blame medical administration for lack of support, but I am not one of them. Pharmacology was given a good start with ample support but failed. Biochemistry, founded at more or less the same time, succeeded. Administrators, perhaps with great perspicuity, apparently felt something was wrong with pharmacology and did not wish to commit university funds to such departments. Although unwilling to drop this subject entirely, they were unable to decide what to do about it as pharmacology seemed different from other branches of medicine, and so it was. Biotropy might solve the problem. It would at least be a true medical discipline, which pharmacology is not.

That we want drugs needs no further comment. Let us consider the purely practical matter of how we are to get them. True it is that the chemist can make drugs perhaps better than anyone else, but he has taught many scientists the secrets of his profession, and more than one biotrepist will be found who can put drugs together as well as many chemists. However, all will agree that the synthesis of chemical substances is a function of the chemist. But if the chemist were to take over this task, what would he make? He already has a million potential drugs on his shelves. Our best chemists are not all biologically minded. In speaking of the great need of a good substitute for quinine in malaria, one of our best-known chemists very emphatically pointed out that this was a simple matter because, as he put it, the malarial organism "is such a damned little bit of a bug." The decision on what types of substances are needed for the cure of disease or for the influencing of a physiological or pathological function is the work of a specially trained biologist, one who knows the organism and disease, and one who also has a working knowledge of the chemistry of the substances with which he has to deal.

If we wish golden eggs, we must have a special breed of goose to lay them, although there are and will be exceptions. An old woman gave us digitalis. Although the biotrepist must be a chemist, he must be much more. He must be trained in the biological sciences and have a knowledge of the reaction of the organism to disease. This does not mean that he must be a skilled clinician. It is not enough to take a chemist, a biochemist, a physiologist, or a medical graduate and tag him as a biotrepist, but he must be put through a long training. We have turned out a few such men, well grounded in the fundamentals of mathematics, physics, chemistry and in the medical sciences, as well as biotrepistry. It can be done, with a plan, as clinicians can be trained, but it takes some ten years or more. For this we need money, which is almost impossible to obtain. We have been most fortunate in having had the co-operation of a broad-minded philanthropist in this, but thus far I have been unable

to obtain the aid of any foundation in training men, although they have been willing to support research. The training of men—students, assistants, as well as the heads of departments—and the imbuing of these men with the spirit of investigation is the true function of a university; mass production is not.

The training of men is no simple matter. In the past one sought out the great masters and absorbed from them not only information but knowledge and wisdom. At present the mass of facts and techniques is so enormous that one is apt to get lost in attempting to acquire them and to overlook that which makes men great. Investigations are no longer simple. More and more factors need analysis; the investigator becomes impatient and wishes assistants, and they in turn wish technicians. All the members of the resulting large group may not be fundamentally interested in the general field of investigation. With such a group, the investigator is no longer free to change his plans, especially as from this group strings run to financial sources, or, to be exact, to the minds of men who with the best of intentions may pull the wrong string and spoil the show. It is axiomatic to say that in a university academic freedom is desired above all else, and for this an adequate endowment is requisite; but let us consider the practical problems of departments of biotrepistry for which budgets from endowment are inadequate, while investigative work of similar nature is being carried out by industrial laboratories under ideal conditions.

There are several methods of operating such a department: First, stay within the departmental budget, regardless of its size, and accept no aid from outside sources. This imposes severe restrictions on members of the staff. Second, accept grants to aid in carrying out work initiated by members of the staff. Third, accept grants to undertake problems suggested by philanthropists or their representatives. Fourth, undertake odd jobs for financial return in order to fill the department, to obtain money for assistants, or to round out the chairman's own salary.

Let us examine the results of these differ-

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ent plans. All of them may allow productive research on a scale approximately proportional to the amount of money received. Universities have been operating for the last generation on the plan of "keeping up with the Joneses." Expansion seems to have been the main objective. However, in biotropy we are beaten at the start in such a race. Industrial and governmental pharmacological laboratories have set standards in size which universities can never reach. On first consideration it would seem that as long as we are beaten, we might as well drop out; and we should if only mass of production is concerned, but quantity of research is not the primary objective of a university. The function of the university is a special one—that of training men, a function which industry cannot take over without in turn forming universities of its own. By co-operation the university and industry can function more economically than by competition. If industry will support the training of men in universities, it will produce a continuous crop of goslings and insure the supply of golden eggs. This is a much sounder and more economical plan than to support competitors or to hand out piecemeal because it can be done more cheaply in university laboratories, and in so doing upset the proper functioning of university departments. If foundations and philanthropists, as well as the public, can be made to see this, the university will become free once more to carry on the main function for which it exists. The training of men, however, does not consist alone in teaching them known facts, but in their learning how to explore the unknown, which involves the complex, indefinable, and unlimited field of research. Dr. Sigerist has pointed out in a most enlightening article, "The University's Dilemma," that the heads of medical departments are becoming so involved in administration that their productivity is being reduced and if steps are not taken to avoid this the better men will go elsewhere in order to carry on their work. It is obvious that the plan of "keeping up with the Joneses" is not a good one as far as universities are concerned.

The solution of this dilemma is to increase the endowment of university departments to

a point where they will become independent. This can be done by educating the public to realize the purpose of universities and, by definite plans on the part of the university, to see that endowment is increased. The latter can be accomplished in the same way that any business concern increases its capital; namely, by not spending all of its income but setting aside a portion of it for capital. It could also be done by requiring that a portion of all grants received be added to the endowment of particular departments. By fixing minimum departmental budgets, and spending a fixed percentage of income only, endowment could be substantially increased over a period of years, and in a university time must be considered infinite. Incidentally, if departmental budgets were made cumulative, it would allow much more economical spending of funds. In order to foster academic freedom in a department, I would suggest, before all else, financial stability; next, the best leader obtainable in the field—not the best administrator, but one interested in the fundamentals. I do not put the man before the money because a good man without sufficient financial support might become a loss to science. Give such a man a respectable salary as suits a respectable man; if we are to breed scientists, guarantee him a minimum salary, a minimum budget, a life insurance and a retiring annuity, and he will be free to devote his energies to his work. Without this, the university is expecting too much of him. With such a plan, a professor, if he wishes, can accept temporary grants to further his own work, but he will feel no urge to expand his department by accepting odd jobs. If he is asked to undertake fundamental research in other fields, he will be free to accept or to refuse. He could collect a group for such work if he desired and delegate responsibility for it to some member of his staff without increasing his own administrative duties, and in so doing he could give his associates valuable experience.

If those wishing to aid mankind by advancing knowledge would put a portion of the responsibility of spending accumulated funds on those who are experts in their fields of science, the former would be relieved of

much of their responsibility and in the long run might, in so doing, accomplish more. It is said by some that the much maligned goose is after all a wise old bird.

Looking into the future we can see the cure of bacterial and parasitic infections with "drugs" and the probability of a chemical understanding of immunity. We can picture also the enormous changes which will come about from nutritional studies when foods, like "drugs," are changing from crude animal and vegetable preparations to pure chemical substances. But have we thought of the complexities of life when enough biotropy is known? Some day we shall realize that we ourselves are, after all, what we know ourselves to be, a mere agglomeration of molecules. With an understanding of the responses of this complex mass to chemical substances, we can not only become fat or thin, but short or tall, and possibly male or female. When even now by the administration of chemical substances a male can be made to produce milk and nurse young, what limit can we set to changes in physical make-up? Thus far, our pleasant drugs, such as alcohol and morphine, are detrimental to our well-being, but similar substances will be found which are not. We know that mental characteristics can be changed by chemical substances. Life will not be simple. We have not yet reached the end of our rope; perhaps it would be better if we had. Imagine getting up in the morning with the

shelves of our medicine cabinets filled with substances which could transform us to fit or misfit the day's work. A little of this and some of that would seem to be the best combination, but then one would discover that he had omitted his "X" and in taking this without due thought had upset the balance between his "Y" and "Z." Jimson's one-a-day pill will not solve such problems. We will have to be "tuned" until everything is in perfect harmony, and only the expert can realize what this means.

The days of synthetic man are here, and here to stay. It would seem time for the medical profession to take steps to handle matters of such importance. A beginning might be made through the organization of departments of biotropy.

I suggest biotropy not as something new but as a change in point of view. Biotropy has always been with us; it is what those in departments of pharmacology have been doing. As soon as it is realized that the study of "drugs" in themselves has no place in our schools of medicine, but that this is a function of the chemist and pharmacist, the first step will have been taken in the right direction. If this can be followed by the organization of departments for the study of the reactions of the organism to chemical substances, we shall be on our way, and if foundations, industry, and the public can be made to realize that it is from well-bred geese that their golden eggs are to come, the way will be clear for uninterrupted progress.

## DO YOU KNOW SOMEONE WHO STUTTERS?

By JAMES F. BENDER

If the totals of the deaf, the blind, and the insane are added, the sum is considerably smaller than that of the number of men, women, and children who suffer from stuttering. Baffling in its manifestations, stuttering is called a sex-factor disorder. For example, statistics on sex-factor disorders tell us that there are approximately three times more women than men afflicted with gall stones; *Daltonism* or color blindness is veritably non-existent among the female sex; likewise, hemophilia, or bleeding sickness, is a so-called male disease because only boys and men are afflicted with it. There is approximately nine times more stuttering among men than women.

Once the reason for this disparity is understood, the problem of stuttering will doubtless be solved. But to date we have only speculations about the phenomenon. Some authorities maintain that women do not stutter as much as men because they have a smaller obscene vocabulary. Stuttering, according to this theory, is caused by a subconscious fear of saying naughty words. Others hold that the difference is due to characteristic breathing habits: females favor chest breathing and males diaphragmatic breathing. The most plausible explanation lies in the theory that females experience a more rapid and stable development than males of the brain centers that are believed to control speech. At least we know that girls speak earlier than boys, have larger vocabularies, and fewer speech defects. In other words, the female sex of our species is more gifted linguistically.

Although known to the Egyptian, Greek, and Roman civilizations, each of which prescribed "cures" for it, stuttering still remains a little-understood disorder. There are fifteen or more contemporary theories as to what causes it and many more corrective techniques. As late as the nineteenth century it was believed that stuttering symptoms could be relieved by surgery. In France alone it is said that more than two hundred stutterers were operated on surgi-

cally during one year. Wedge-shaped portions were cut from the back of the tongue and various lingual muscles were severed. The tongue was also pierced with needles or cauterized. Sometimes wooden wedges were placed between the teeth. Smoking was often recommended as a sedative to the vocal cords, which were believed to be the main seat of the difficulty. Much earlier, Francis Bacon maintained that the stutterer's fundamental derangement was caused by a cold tongue which needed to be warmed throughout the speaking day by imbibing good, hefty wine. These, and many other, rather bizarre remedies were advocated because stuttering was looked upon as an organic disease. Today that point of view is not widely held.

Whatever the cause or causes, the effects of stuttering are extremely painful psychologically. Here are a few excerpts from autobiographies of stutterers.

As a stutterer, I experienced a rather consistent bodily and mental state. The defect does not exist merely as an obvious inability to express myself adequately in speech; it involves a generally complicated bodily tenseness as well, and mental uneasiness, a real fear which is apparent as a rule in my halting, shrinking manner of expressing myself, my thoughts, my emotions. I tend to hold myself in because I am afraid I shall stutter.

Although I believe I was as physically attractive as most of the girls I went with, I never had the invitations that they did to go to dances and other affairs with fellows. I always had a suspicion that they made fun of my stuttering behind my back. Consequently, I never married. No one ever proposed to me.

I was terribly shy around them [girls] when not in the classroom. However, I do not think I would have been if I had not stuttered. When I saw other boys talking to some of the girls I liked, I felt envious, and even hated myself because I could not talk to them too.

My only enjoyment was to work alone in the fields and dream of what a great success I was going to be. My success pictures always had the foundation of perfect speech. I disliked working with anyone. That called for conversation and would not let me dream.

Soon I shall be fifty years old, and while I have much to be thankful for, especially in the way of a

good wife and two fine youngsters, I have been a vocational failure because of my stutter. As the years have rolled along I have seen many men, without as much ability as I have demonstrated, supersede me in rank and salary. Without exception they were competent speakers, and I was a tortured one. Why isn't something done for the stuttering child before he gets too old?

These confessions reflect only a small portion of the characteristic torture that stuttering ordinarily entails. Multiply such experiences by the total number of stutterers in the United States (a conservative estimate being 1,350,000 men, women, and children who stutter), then add the relatives and associates of the stutterers and the results indicate that a tremendous number of people are directly interested in this ancient and as yet unsolved problem of speech and its blighting effect upon the personality.

Within very recent years this interest has been crystallized in research into the problem and the establishment of speech clinics, especially in our leading colleges and universities. As the result of laboratory experiments and surveys, we now know that there is a marked tendency for the onset of stuttering to fall into three periods of life: when speech develops, which is normally around two years of age; between five and seven years of age; and during adolescence. Stuttering usually begins during the first decade of life. Stuttering symptoms do not ordinarily make their primary appearance after a person has matured physically, although they may be intermittent; that is, the symptoms may disappear more or less only to recur at some later time. Even the most confirmed stutterers experience alternate periods of severity and mildness of the disorder. These cycles may vary greatly in duration. Another interesting fact is that more children than adults stutter. This accounts for the widespread and erroneous belief that the trouble is usually "outgrown." Some stutterers reveal their speech disorder only in reading aloud; others, just in speaking; still others, in both activities. For example, certain famous actors and preachers have stuttered consistently in conversation but not in platform speaking. Stutterers can sing without blocking on words, ordinarily they can read successfully in unison with others, and they invariably report that they can talk

to themselves when alone without any difficulty. Many of them talk fluently when addressing a much younger or inferior person. One research worker has reported that stutterers can talk with complete fluency while crawling on their hands and knees, even when others are present.

If one were to select one hundred stutterers at random and match them with non-stutterers in regard to age, intelligence, social background, and other such factors, and then trace the speech characteristics of the forebears of both groups, one would probably find six times as many stutterers in the ancestors of the stuttering group as in those of the nonstutterers. In families in which twins tend to recur one may expect to find about five times as many stutterers as the generally anticipated number. Such findings point to heredity as the chief predisposing cause of stuttering.

Why do more children stutter than adults? Once again we can only offer plausible explanations. One research worker has found that stuttering speech in young children learning to talk is more usual than not and that more than 40 per cent of all young children whose early speech is marked by stuttering symptoms "outgrew" them. Perhaps the theory of primary and secondary stuttering is helpful at this point. Primary stuttering is identified by the characteristic gasping breathing, blocks and repetitions on sounds and syllables, tensions and nervousness, and twitching. Psychologically, primary stuttering is marked by unawareness on the part of the afflicted child of the social discomforts that his speech disability entails. Secondary stuttering, the reactions of the stutterer to his speech handicap, is rarely recognized as such until the child is old enough to realize that his mutilated speech results in feelings of unpleasantness—of inferiority and frustration—in social situations. When the child leaves the protection and the sympathy of the home to go to school, the symptoms of secondary stuttering are likely to become evident. If parents nag or show too much concern about the primary stuttering, they may actually encourage the secondary phase, which is generally more difficult to correct. Authorities recommend that the stuttering child be referred to an expert as early as

possible because secondary stuttering, if allowed to develop, fosters personality problems which are likely to grow in complexity with advancing age.

Much has been written about the forced change of left-handedness as a cause of stuttering. The theory is based on the knowledge that the left side of the brain controls the movements of the right side of the body, and, conversely, the right side of the brain controls the left side of the body. It is also based on the hypothesis that the side of the brain that controls the preferential hand, especially in writing, also is the dominant factor in controlling the co-ordinated muscular movements which produce fluent speech. Hence, if handedness is changed by force, stuttering is said to result frequently. Results of surveys do not bear out the contention that all, or most, stuttering is caused by forced change of handedness. In one of the studies that involved 89,000 St. Louis school children, "the vast majority of our left-handed pupils who have been taught to write with the right hand had not developed any speech defects." Moreover, "81.4 per cent of the children for whom definite data were supplied began to stutter before they were given any instruction in writing in the schools." Nevertheless, most psychologists and educators today do not advise the forced change of handedness. "Let nature take its course in this respect" is their advice.

The stutterer frequently gives the impression to many people of being slow of comprehension or even below normal in intelligence—probably because fluent speech is rated so highly in everyday life as an index of intelligence. As a group, however, stutterers are at least normal in intelligence, and there is some evidence to indicate that they are above-average in this respect. For instance, a study of the speech characteristics of a large group of feeble-minded children and adults revealed that almost all kinds of speech disorders were distributed among them *except stuttering*. Again, stuttering is twice as prevalent among students of colleges and universities as among the general population. Moreover, Havelock Ellis reports "the abnormal prevalence of stuttering among British persons of ability." These pieces of evidence, together with the

results of intelligence tests of stutterers, indicate that stuttering is not associated with feeble-mindedness; rather, stutterers tend as a group to be gifted mentally.

Despite their intelligence, stutterers need guidance in the solution of their speech and personality problems. It is difficult for them to attain an objective view of their disorder and themselves. If the stuttering has been neglected in their childhood, there is still hope for speech improvement, because stuttering symptoms can be brought under control and in many instances a complete correction is possible. While there is no panacea or magic formula for the correction of stuttering, there are many helpful techniques available for its alleviation. The age and personality of the stutterer determine in large part the corrective approach. But the stutterer needs to beware of the individual or organization that guarantees cure, because there are too many unknown factors in each case of stuttering to warrant such a rash promise.

As an example of one approach to the alleviation of stuttering, the case of Mary, three years of age, is cited. She was an only child who began to stutter when her mother was taken to the hospital. Prior to that time the little girl had been carefully protected from outside contacts and was not permitted to play with other children. During the mother's illness, Mary lived with an aunt, an uncle, and three cousins, four, six, and seven years of age. By the time that Mary returned to her own home she was stuttering quite noticeably. The thought of revisiting her aunt's home was a case of anxiety. She had doubtless experienced a good deal of nostalgia and unhappiness in the strange environment. One of the results was stuttering. The parents were advised to put the child to bed for two days, and a regimen of relaxation and quietude was prescribed. Radio programs were kept to a minimum. Romping and contacts with outsiders were ruled out for the time being. The parents were cautioned not to dramatize the stuttering by suggesting to Mary to speak smoothly or slowly; nor by making sympathetic facial expressions; nor by talking about the stutter. Rather, they were encouraged to ignore it and to speak without excite-

ment and to wait for Mary's words with disarming patience.

Within two weeks Mary was speaking with her former smoothness. After the old speech habits were re-established, Mary's mother was encouraged to widen the youngster's social contacts; but to widen them gradually and to select playmates whose speech was exemplary.

If Mary had been given formalized speech training upon her return home she would probably have become so speech conscious that the stuttering symptoms would have increased in severity or become tenacious. The approach was indirect as it should be in the tender years when primary stuttering takes place, before the child is cognizant of the value put on normal speech by her associates.

An entirely different approach was used to help Mr. X, a business executive of forty years of age. He had stuttered most of his life and had undertaken various kinds of "cures" from time to time. But a promise of a substantial promotion and added responsibility, contingent upon his acquiring control of his speech, gave him a strong incentive to do something about it in a sustained way.

The psychologist explained to him that only he could help himself. That he might well adopt the attitude that his stuttering could not be cured in any miraculous way. But by relearning to speak through conscious management of the speech process, he could at least control the symptoms of stuttering.

Training was then given him each morning, before he reported for work, in *rate-control*, a technique of speaking based upon phonetic analysis designed (1) to awaken aural speech consciousness, (2) to permit accurate diagnosis and isolation of habituated articulatory and vocal defects, (3) to relax the organs of articulation and use them economically, (4) to induce mental ease while speaking or reading orally, (5) to improve vocal quality, (6) to develop conscious control of the mechanical factors of articulation, and (7) to enlarge breath capacity. These principles were applied to the oral reading of sounds, then syllables, and then words, and finally phrases and sentences. Once the technique was mastered in oral

reading, the same principles were applied to improvised speaking. He was asked to talk about pictures that were flashed to him. After this step was mastered, he was requested to talk impromptu about a scale of subjects that required ever-increasing attention to the subject matter, always using a rate that allowed him to speak smoothly. The final step was to apply rate-control over the telephone and before a formal audience.

In the case of Mr. X the time required for him to relearn to speak was a year. He visited the psychologist every day, including Sunday, for the first two weeks. Then followed a month of visits on alternate days. He came twice a week for the subsequent five months and once a week thereafter until his speech was completely under control.

Along with the speech re-education went discussions about matters pertaining to his attitudes toward himself and his associates—mental hygiene—for Mr. X, like so many seasoned stutterers, had developed characteristic maladjustments of temperament. As Mr. X's speech improved, his attitude toward himself and a great many things changed for the better. The vicious circle had been broken as soon as he had learned that he could control the speech symptoms of stuttering.

Mr. Y, another business executive of age and background comparable to that of Mr. X, found *voluntary stuttering* a helpful re-educational process. Voluntary stuttering is based on the theory advanced by Dr. Knight Dunlap that "repetition may be employed in dissolving or breaking habits as well as in the formation of habits." The assumption is that stuttering is a collection of undesirable habits that can be eliminated by voluntarily repeating them. Psychologists and speech clinicians who use the technique of voluntary stuttering usually have the stutterer repeat the first sound in each word distinctly and clearly several times, varying the number of repetitions at the beginning of words to avoid establishing a set speech pattern. Whenever a stutterer has a speech spasm while using voluntary stuttering, he is requested to repeat the word until he can say it without difficulty. In the case of polysyllabic words, voluntary stuttering may be practiced on each syllable, each initial

syllable being assigned varying sound combinations; thus, for example, s-s-s-stutter or st-st-st-stutter. When the mature stutterer has tics and other nervous mannerisms, he is taught to control them by reproducing them voluntarily before a full-length mirror.

Both rate-control and voluntary stuttering are only two of a large number of re-educational techniques. They are mentioned here to illustrate the old adage, "What's one man's meat is another man's poison." Mr. X found relief in the former and not the latter; and Mr. Y's experience was the exact opposite. That is why the psychologist who handles cases of secondary stuttering needs to know many approaches and to be able to select the most helpful for each individual case. Sometimes he employs a combination of techniques. For example, both Mr. X and Mr. Y were given daily progressive relaxation exercises along with their respective speech re-education techniques. Like most other therapeutic approaches involving human contacts, speech correction is an art as well as a science. The important consideration is that stutterers cannot be put

into a Procrustean bed. Each case must be approached to meet its peculiar needs.

Perhaps the most significant single item in the correction of stuttering is the rapport established between the stutterer and his correctionist. The value of rapport, the reciprocal feeling of friendliness and confidence, cannot be stressed too heavily. Once rapport is established the stutter can be attacked by one or more of a variety of techniques known to the specialist. Fundamentally it is because of rapport that so many techniques prove successful. Of equal importance to the stutterer is his need to accept his disorder of speech as part of his fate. He must not feel too sorry for himself, but meet and know the large number of people of accomplishment in all walks of life who have been stutterers. It is the nature of all of us to be handicapped in some respects: stuttering, like chronic indigestion or procrastination or shyness, can often be corrected completely or diminished in severity or compensated—if only the stutterer will give himself the opportunity, and progressive communities will make that opportunity possible.

#### TO GENE

*When I inquire of organismal forms  
Where lies the structure that declares them one  
Amid diversity, which like the sun  
Uniting orbits, limits countless norms  
In orthogenic line or spreading tree,  
Providing adaptations for each load  
In evolutive or regressive mode  
As earth's climatic cycles shall decree.*

*I come upon a molecule, immense  
Within the microcosm, limitless  
In numbered combinations, hardly seen,  
Yet known by chromosomic loci in extense,  
A protean form in polymeric dress  
A fascinating neatly coiling gene.*

—JOHN G. SINCLAIR

# THE PROBLEM OF ORGANIC FORM

## I. BUILDING THROUGH FUNCTIONING

By S. J. HOLMES

WE commonly look upon embryonic development as a building process in which organs begin to function only after they are formed. It may seem absurd to say that the stomach functions before it acts upon food, and so it would be if we interpreted the term function in the way it is commonly employed. But the stomach does much more than digest food. Like other organs, it assimilates, respire, excretes, produces hormones, and responds to stimuli in many ways. The functioning of all organs involves morphological changes which may be very inconspicuous or at times quite extensive. That structures are in part formed, as well as maintained, through the effects of their activity has long been known. To what extent can we regard such formative effects as explaining the phenomena of embryonic development and regeneration?

The important role of functioning as a building process was especially emphasized by Wilhelm Roux, one of the great pioneers in the field of developmental mechanics. He divided development into two chief stages, the first of which is the period of self-differentiation, in which parts are formed "without requiring therefor the exercise of function." "The second period is the period of formation through functioning," which leads to a further elaboration of structures previously laid down and effects the harmonious interadjustment of all the parts of the organism.

The events of the earlier period in which the organ systems are blocked out and started on their careers of differentiation were interpreted mainly as expressions of heredity. Roux's experiments on the early development of the frog's egg convinced him that the cells differentiate at first as independent units. Whatever harmony there might be in their developmental processes was conceived to be a sort of pre-established one; but, obviously, nicely co-ordinated differentiations could not go on indefinitely, or even very

long, in independent parts. Roux therefore concluded that as the embryo becomes more complex the functional interaction of its parts comes to play a role of increasing importance.

Roux's exposition illustrates the common conception of the distinction between building and functioning. He was willing to concede, however, that although an early embryo is a mosaic of independently developing parts, each self-determining element may develop through the interaction and mutual determination of its smaller components. Periods of irreversibility step in at various stages of ontogeny, first for the larger areas or organs, such as the neural tube, and then for smaller parts of each, although leaving the final product with sufficient plasticity to provide for minor structural modifications. Although a proponent of the so-called mosaic theory of development, Roux was fundamentally very much of an epigenesist.

The names of Roux and Weismann are frequently coupled in referring to the so-called Roux-Weismann theory of development. Both of these leaders of biological thought essayed the formidable task of developing a mechanistic interpretation of life, although they wrought out their ideas in different but overlapping fields. Weismann was concerned chiefly with problems of heredity, variation, and evolution, but he later incorporated a theory of embryonic development and regeneration as a part of his general system. Roux endeavored to throw light upon the causal mechanisms of development and direct adaptation. Both were thoroughgoing selectionists and looked upon natural selection as the great explanatory principle by which the apparently teleological features of the organic world can be explained in terms of mechanism; and both devised extensions of the selection principle (Roux's struggle of the parts, and Weismann's germinal selection) to make it cover cases for which the original Darwinian doctrine was

deemed inapplicable. Both postulated a considerable degree of preformation in the egg as to diversity of content and as to the arrangement of parts, and both at first appealed to qualitative nuclear division as a means of securing the proper distribution of formative germinal factors. Roux was wise enough to abandon this latter doctrine, but Weismann was led to elaborate it further. In Weismann's conception, development is primarily a sorting process, and to explain why the right determinants can be located in the right places at the right times he postulated an "organization" of the germ plasm such that the developmental factors would be properly placed through the normal process of qualitative nuclear division.

Researches in experimental embryology, however, dealt telling blows against Weismann's theory of development, and the superstructure crumbled and fell. The early experiments which seemed to favor the mosaic theory were soon followed by others which showed its untenability as a general doctrine. Differences in the behavior of mosaic eggs and so-called regulative eggs are now readily interpretable from a common standpoint. Due more to the geneticists than the embryologists, experimental or other, the old problem of preformation has to a large extent been solved, at least in principle. The geneticist can point to a map of the chromosomes and say, "Here, gentlemen, is the preformed basis of development. We have not, of course, discovered all the genes, and although we cannot tell just what genes are, we can tell very precisely where they are. Nevertheless, the general outline of the picture of the genetic factors controlling heredity and development is fairly clear."

As a result of many experiments on the eggs of many animals, it is now established that the prospective fate of the various parts of an egg is largely determined in an epigenetic manner. Even the most mosaic egg closely approaches, if it does not actually become, an equipotential system if we take it at a sufficiently early period. All eggs have a certain amount of cytoplasmic organization that stands in various degrees of constancy to the location of future organs. But this organization is at first labile and becomes

fixed at very different times in different groups.

As a consequence of numerous researches on the influence of organizers and other factors, biologists have become more and more prone to look upon embryonic development as a series of responses to stimuli. Response to stimuli is, of course, a very broad and general category. Real progress toward understanding development is made only when the nature, location, and mode of action of the stimuli are ferreted out and when we learn how responses are co-ordinated in such a way as to produce regulatory results. The older theories of epigenesis which attributed development mainly to the interaction of parts contained no adequate explanation of the regulatory adjustments which are essential to normal development. The same statement applies even more strictly to the theories of preformation. In most theories of development regulation is regarded as due to a sort of collateral agency, doing nothing so long as everything goes right, but ever ready to patch things up when they go wrong. It may be compared to a repair man working along with a builder who slavishly follows a plan outlined in the structure of the germ plasm. A small change in the foundation may cause the builder to deviate from the proper course of construction, which would make a sad mess of his undertaking did not the repair man step in and undo a lot of his work and start it off on a new line. The builder can follow a plan laid out for him, but he lacks the aptitude for making adjustments. These must be left to his much more resourceful companion, who often exhibits considerable ingenuity in employing new methods of achieving his ends. At times the structure may be half destroyed, or it may be remodeled on a new orientation and partly rebuilt. Then the repair man has to take over most of the work and boss the entire job.

Some such conception of the relation between formation and regulation is common. One finds it quite clearly revealed in the writings of Weismann. It is given frequent expression by Roux, who regards self-differentiation of early embryonic cells as typical, but when abnormal relations occur as in the separation of blastomeres or the fusion

of eggs or blastulae to form normal giant embryos, "the whole formation stands over the parts and directs their development," i.e., the regulative power of the whole takes command and overrules the autonomy of the components of the mosaic and makes them conform. Most epigenesists who extended the period of interaction over the entire history of the embryo had no clear explanation of why interaction leads to a norm instead of disorganization. Roux tried to remedy this common defect of theories of development by elaborating his doctrine of the struggle of the parts of the organism. He attempted to apply this principle to explain direct adaptation through overcompensation, functional hypertrophy, and other processes which he showed were involved in the functional period in development. But in his employment of the idea of struggle, as I hope to show in another article, he lost sight of an important consideration, omission of which seriously impaired the value of his theory.

The general failure of mechanists to devise a satisfactory theory of regulation has given much comfort to the vitalists and other opponents of mechanistic theories. The problem of explaining how behavior that seemingly makes for the realization of ends can be accounted for in terms of causally determined activities presents a perpetual challenge to the mechanist, but I think it can truly be said that he is being brought nearer his goal through the significant results of research in a number of fields. Among these we may mention (1) the work of the experimental embryologists; (2) the researches of the geneticists who attempt to ascertain the precise ways in which genes produce their effects; (3) researches by means of X-rays and other methods upon the molecular structure of proteins, the organization of crystalline formations, and the structural patterns assumed by colloids—researches that have opened up fruitful fields in which discoveries of importance for the basic problems of the organization of the cell may be expected at any time; (4) studies on the functions of enzymes, their interactions, and their relations to colloidal structure; and (5) the discoveries of the physiologists, who are revealing the mechanisms by which functional cor-

relations are effected between various organs of the body. Much recent research in physiology has been devoted to the analysis of the interadjustments which lead automatically to functional balance, or what Cannon has called "homeostasis." These have a very pertinent relation to problems of morphogenesis simply because they deal with the mechanisms of regulation. Our bodies are mechanisms so constituted that they respond to stimuli by checking excesses and speeding up deficiencies in the performance of their several functions. We now know much concerning what these stimuli are, where they arise, and the effects they produce on particular organs. And insofar as we can give a causal explanation of their action, we are contributing also toward giving a causal explanation of change of organic form.

Analyses of these interadjustments have shown that they are effected by a number of quite different mechanisms. Hormones, vitamins, mechanical stresses and strains, nerve impulses, products of excretion, and even such simple substances as carbon dioxide are instrumental factors in the processes of adjustment. A highly significant role in homeostatic regulation is played by the bodily fluids, or *milieu interne*, which is much more exacting in requiring proper bodily responses than are the external surroundings of the organism as a whole. Largely a product of the body, it is, except for a few free cells, nonliving. And yet one might almost call it half alive. It has certain aptitudes for self-regulation and makes responses to living cells around it. If it receives acid, it draws upon its alkali reserves to help maintain its normal pH. If it receives OH ions, it proceeds to neutralize them. But these reactions in maintaining an approximate status quo are powerfully reinforced by the living cells which react to its slight chemical changes in ways that tend to keep its composition constant. Long ago the great physiologist Claude Bernard stated that "all the vital mechanisms, however varied they may be, have only one object, that of preserving constant the conditions of life in the internal environment," a statement which so strongly impressed another physiologist, J. S. Haldane, that he declared: "No more preg-

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Except to a limited extent confined to highly developed types, organisms have to take their external environment as they find it, but their *milieu interne* they largely make for themselves. From the simplest of beginnings both in phylogeny and in ontogeny, this *milieu interne* has taken on more and more numerous and varied functions as life processes have become more complex. Its functions are intermediate and instrumental as steps in effecting interadjustments. Its constancy must be maintained if it is to serve in so many ways as a means of integrating the physiological and morphogenetic activities of the organism.

The various regulatory processes whose action Cannon has described in his interesting volume, *The Wisdom of the Body*, cannot be divorced from a certain amount of structural change which may be morphogenic in varying degrees. Familiar illustrations are afforded by the formation of callouses, the hypertrophy of heart muscle in valvular deficiency, and the response of the uterine wall to estrogenic hormones. Cell growth and cell multiplication are integral parts of many of these functional adaptations, but between changes small or great studied by the physiologist and the apparently purely constructive operations falling within the province of the embryologist there are many gradations. As Roux has shown, functional hypertrophy plays an important role not only in ordinary functional adjustments, but in effecting the development of organs in the so-called functional period of development. These hypertrophies are often traceable to reactions to specific stimuli. The increased development of mammary glands in preparation for lactation is effected through the influence of hormones. Under proper endocrine control even the rudimentary mammary glands of the male rat may develop to full functional efficiency. More extensive building initiated by hormonal influences occurs when the removal of the left ovary of a fowl is followed by a growth of the minute right gonad; and where castration in the male toad is followed by the transformation of Bidder's organ into an ovary and the subsequent con-

version of the rudimentary Müllerian ducts into oviducts. In such cases it is reasonable to assume that the stimulating agent first evokes a certain type of metabolism, perhaps merely increasing a kind that is already going on to a mild degree, and as a result enhancing a specific kind of functioning.

We should look upon functional hypertrophy not as a more or less exceptional emergency reaction, but as an all-pervasive process appearing at all stages of ontogeny from the growth of the unfertilized ovum to the final integrative effort to sustain life. I imagine that it is very busy in the passive-looking cells of a frog's blastula. Each of these cells has many developmental potentialities. Recent investigations on the isolation of parts of early amphibian embryos and their combination in various relations have shown that the direction in which the cells differentiate is determined to a remarkable degree by the kind of association in which they occur. Organ-forming proclivities normally manifested are often over-ridden and directed into new channels that harmonize with the immediate neighborhood. At first the metabolism of these cells is presumably much the same throughout, and the differences that soon appear may be at first only differences of degree. Each cell gives out substances that may influence the metabolism of contiguous cells. In this way certain cells act as organizers to their neighbors, which in turn act as organizers to less specialized areas. One region takes the lead and the rest of the organization shapes up around this starting point. We must regard this inert-looking blastula as a complete organism composed of parts with diverse but complementary functions. We know little of its peculiar physiology, which doubtless includes such activities as assimilation, respiration, excretion, diverse metabolic changes in different parts, tendencies toward differential growth and movement, production of different organizer substances, generation of electric currents and radiations with their possible mitogenic or other effects, and much responding to stimuli. The mosaic period of development is a sort of terra incognita in which unanalyzed processes have been vaguely ascribed to heredity because they

could not be attributed to anything else. It seems reasonable to suppose that much of the integration going on at this stage may be due to hormones or to substances having similar functions. The reactions to organizer substances are largely morphogenic, although they may also be a part of physiological regulation. They are manifested early as differential movements through which gastrulation and other formative activities may be effected, but also internal structural changes are set up which result later in histogenesis. The early histological changes are presumably subsidiary to the discharge of functions carried on by the cells of the blastula. Further specializations of structure go hand in hand with the increasing diversification of functional reactions.

As an illustration of the viewpoint here presented let us suppose that an organism is composed of four parts, A, B, C, and D, with specific kinds of functional activity. They stand in homeostatic, or essentially symbiotic, relation such that if A functions beyond a given rate some other part or parts affected will produce some kind of stimulus, perhaps a hormone, which will inhibit the functioning of A. If A functions less rapidly than a given rate, other parts react by producing stimuli that goad A into more vigorous action. Similar relations obtain for B, C, and D. The result is that a certain constancy, or balance of functional performance is automatically maintained. The organism is a self-regulating mechanism because it is so constituted that each part responds to the reactions of its associates by speeding up or slowing down its rate of functioning according to the kind of message it receives. One of the most noteworthy features of recent physiological research is the discovery of more and more cases of the kind of relationship between organs here described. But one may object that functional balancing can be explained only when there is an adaptive mechanism to start with, just as one can explain the regulation of time-keeping in a clock. And as a clock does not build itself, so, it may be claimed, we must look to something besides the organism's own functioning to explain its structural make-up.

But organisms really do build themselves

through functional adjustments. The only question is as to how far the process can go. Can we say that the whole process of development is just one grand series of homeostatic efforts? This, I concede, is quite too sweeping and grandiose a generalization to be justified by the facts, since there are certain morphoses not evoked by homeostasis. Nevertheless, the structural developments due to balancing may be sufficiently numerous to become the chief guiding influence of ontogeny. In accordance with this interpretation the adaptations of ontogeny with the regulatory activities operating at every turn, bringing about co-ordinated growth processes, inhibitions, unbuilding and starting along different lines, repair of injuries, and various other integrative processes, both normal and exceptional, are susceptible of essentially the same kind of explanation as the interadjustments of the functions of the adult body. One may conclude, therefore, that formative physiology and functional physiology are one.

The period of self-differentiation is quite as much a functional stage as any other stage of development. It is through functional interaction that the self-determining areas are first blocked out, and it is by the same means that the subordinate regions of each are differentiated into harmoniously organized parts. Early co-ordination is, like the co-ordinations in the behavior of primitive animals, largely effected by a step-by-step process. Parts early organized act in turn as organizers. Each step in morphogenesis may be regarded as a matter primarily of functional adjustment, a part of the general process of homeostasis, or balancing, as much as the various processes subsumed under this name in the adult body. One might conceive of the integration of the first developmental stages of the frog's egg as resulting from hypertrophying one or another of the primary physiological processes of the cell. We know little of the steps by which the physiology of the blastula becomes converted into the physiology of the mature body, but the process must be one of continuous orderly evolution, like the increasing elaboration of embryonic structures.

In the higher animals the step-by-step

method of securing co-ordination is supplemented by the evolution of two important organ systems, the endocrine glands and the nervous system. Increase in size to be effective must be conditioned upon the development of means of readily co-ordinating the activities of remotely situated organs. Although every cell may be assumed to produce hormones or some other substances which diffuse out and affect contiguous parts, the endocrine organs of higher animals elaborate secretions that exercise a much wider influence. Such action is greatly facilitated by the movements of the blood and lymph, and it may result in marked changes in form as well as in function, as is illustrated by the morphogenic effects of the secretions of the thyroid, anterior pituitary, and the sex glands. Equally striking are the morphogenic changes effected by the nerves. The transformation of ordinary epithelial cells into taste buds under the influence of contact with sensory nerve endings and the reversion of these cells to epithelium after the nerve supply is cut are illustrative of the morphogenic potency of nervous influence. The sensory nerve ending is apparently an organizer for the development of taste bud cells. We may say that nerve endings affect the metabolism of these cells in such a way that they respond by manifesting a new potency. This morphogenic influence is probably chemical like that of the endocrine glands. Physiological investigation has shown that nerve cells and their processes really are endocrine glands secreting acetylcholine, adrenalin or some similar substance, and possibly other products. Nervous co-ordination and endocrine co-ordination, therefore, rest on a common basis. The nervous system performs its endocrine functions much more precisely than the other endocrine organs. We might define nerves as chemical applicators analogous to those employed by a rhinologist who applies a chemical to a particular spot of one's nasal membrane. By applying its hormones in sharply restricted areas the nervous system is able to function efficiently in securing nice and delicate co-ordinations required in the life of the higher animal.

The development of long-distance co-ordi-

nators introduces nothing essentially new in addition to the integrating mechanisms of early ontogeny. At all stages we are dealing with the response to chemical substances producing formative as well as physiological reactions of an integrative sort. Some of the substances are hormones in the restricted sense; others may be as simple as carbon dioxide, which is an important factor in regulating respiration and the hydrogen ion concentration of the blood.

The organism is always building to meet present requirements of functional equilibrium. Its parts may function later in a quite different way, but that has nothing to do with physiological mechanisms of their production. Homeostasis occurs at every stage of ontogeny, and whether the reactions are predominantly morphogenic or physiological is incidental upon the conditions prevailing at any given period of development.

The whole trend of research in experimental embryology is to bring embryology and physiology into more intimate relationships. But whether or not formative actions attributed to organizers are designated as functioning is of little importance so long as we recognize that such actions are subject to regulatory control at all periods of development through the mechanisms of homeostasis.

Any analysis of developmental processes soon brings us face to face with the obscure problem of histogenesis. That the way in which a cell differentiates may be a result of its peculiar organic setting is a frequently demonstrated fact and may be determined by the kind of genes which are aroused to their specific enzyme activity through the evocatory influence of co-ordinating parts. Gene expression, as is well known, may be influenced by environmental factors. Whether the genes are autocatalytic enzymes or are the producers of enzymes, we may reasonably assume, as is often done, that they have the capacity for setting up a great variety of chemical changes which have different morphogenic effects. We may suppose also that the reactions which the genes have been attuned to perform through the long action of natural selection are of the kind that make for functional integration and harmonious morphogenic differentiation.

Natural selection has constructed organisms to respond not only to outer stimuli by proper behavior, but also to internal stimuli by appropriate functioning and morphogenic reactions. Life is not only "the continuous adjustment of internal relations to external relations," as it was defined by Spencer, but the continuous adjustment of internal relations to other internal relations. Through the first the organism is preserved; through the second it is not only preserved but built.

Assuming, then, as a very tentative hypothesis, that the course of building the organism has been largely guided by reactions evoked in balancing physiological activities, we must postulate that the latter in turn depend upon physical and chemical processes, some of which are directly morphogenic. We may call these the primary morphoses. The fairly definite pattern assumed by the fibrous structure of some colloids under the influence of external stimuli suggests an origin akin to that appearing in certain crystalline formations. One might by a sufficient stretch of the imagination look upon the structural pattern of a muscle cell or an infusorian as an expression of the way in which the protoplasm forms a gel. The tendency of gels to produce more or less definite patterns under the influence of external stimuli may have much to do in determining the specific types of cell structure appearing in histogenesis. We are here dealing with basic physical and chemical factors of form production which may underlie the physiological processes involved in the co-ordination of organs. But granting that the formation of cell structures may be accounted for in part as a result of processes akin to crystallization and the pattern formation of gels, it would seem absurd to apply the same explanation to the complex organization of a bird or a mammal, especially since the goal attained is not something fixed, but is a moving equilibrium assuming countless forms from the egg cell to the senescent body.

But even the building stones must be fitted

for their proper places. Typically a crystal is a fixed form with the same molecular composition throughout. But in an organism the substances which tend to build themselves up into patterns under the influence of their polarities are varied and continually changing. At all stages they are affected directly or indirectly by the differentiating influences of genes. They are affected also by the organizing influence of substances and possibly peculiar forms of energy received from other cells. The pattern into which the proteins of one cell tend to gel may be changed through chemical or other actions set up through the influence of its particular cellular environment. The primary morphoses and more complex physiological reactions play interacting roles in the integration of development and regeneration. The cytoplasm of early embryonic cells has the potency of forming a great variety of structural patterns. The possibilities of variation in protein composition are almost endless. But the patterns built up in one part under the influence of physical and chemical processes may depend on the kind of functioning that goes on in another part. Even these purely physical and chemical pattern building processes are under the guidance of genes, and their activation is subject to a sort of social control by their organic environment.

The main problem in form production is the proper ordering of the many physical and chemical morphoses which the protoplasm of a species is capable of undergoing, and hence an adequate interpretation of organic form must include an explanation of morphogenic processes on the physico-chemical plane combined with an explanation of integration on the physiological level that may exhibit relationships to the phenomena of social life. In isolation these physico-chemical morphoses seem stereotyped enough. But when properly combined in an organism their aggregates become subject to a sort of democratic control and may exhibit an unexpected capacity for self-government.

(To be continued)

## SCIENCE ON THE MARCH

### WHITHER PETROLEUM?

MANY of our ancestors of a century ago had not heard of petroleum. Some along the advancing pioneer front had encountered its use by Indians, who obtained it from seepages. Our grandfathers began to hear more about it and to use a derivative in the "coal oil" lamps which were displacing the common tallow candles. One of the most revolutionary sources of power—the internal combustion engine driven by petroleum derivatives—did not have commercial application until Daimler in 1887 successfully produced a motor car. Now, the high stakes in World War II are being gambled over the globe by use of indispensable supplies of petroleum to manufacture rubber, plastics, TNT, and other materials and to power and lubricate almost countless machines on land and sea, in the air, and under the sea.

What an amazing contrast has developed in a half century in the use of petroleum, to the end that this generation has come, unconsciously perhaps, to assume unlimited petroleum as an inalienable birthright!

General opinion credits the discovery of petroleum in this country to the oil well drilled in 1859 by Colonel Drake near Titusville, Pa. This "discovery well" was presumably a wildcat venture. The operation was based on improvements made in drilling tools and technology since the first well was successfully drilled in 1808, in the search for salt water, at the Great Buffalo Lick near Charleston, W. Va.

The Drake well was a historic landmark in the deliberate search for petroleum. Several earlier discoveries of oil had been made, incidentally and often exasperatingly, in drilling wells for salt and later for ground water. It was reported in 1833 by Hildreth, the Ohio Valley geologist, that a well bored for salt in 1814 near Marietta, Ohio, supplied enough petroleum to be marketed for lighting purposes. That well apparently was the first petroleum well in the United States. Between 1814 and 1859, at least ten other wells containing natural gas or petroleum were drilled in Ohio, West Virginia,

New York, Kentucky, and Pennsylvania. The gas and oil were accessories, of limited local use, to the desired salt or ground water.

The sensational Spindle Top gusher near Beaumont, Texas, began to flow in January, 1901. Unlike any well drilled previously in the United States, it sent almost continuously a 6-inch stream of oil to a height of 160 feet until it was capped nine days later. The daily flow was conservatively estimated to have been 70,000 barrels. One wonders as to the productive capacity of this well if the diameter had been twice as large. Within three years more than 40,000,000 barrels of crude petroleum had been obtained within a radius of 30 miles from Spindle Top. What a contrast with the total oil production in Texas in 1895 of only 50 barrels! California in the same year was producing more than a million barrels of oil, but the production in Oklahoma was only 37 barrels.

Discoveries during the next several years signalized the development of an epochal industry whose future could scarcely have been fully imagined. The rapid progress in discovering and developing new fields throughout the United States and Canada revolutionized American industrial economy and changed radically the American mode of living. During the last third of a century the numerous indispensable products of petroleum have become commonplace, even in remote hamlets throughout North America. In the relatively short span of World War II, they will become familiar around the globe.

One billion barrels annually of petroleum in the United States was for the first time produced in 1929. It was derived mainly from nineteen states. Texas, California, and Oklahoma yielded more than 824,000,000 barrels. Production declined somewhat during the lean years of the depression but was again more than a billion barrels in 1936. It reached a peak of more than 1.5 billion barrels in 1943. This production was chiefly from twenty states with about half of it from Mid-Continent fields. California and the

Gulf Coast each contributed more than a quarter billion barrels.

Whither petroleum in the near future and in the long-range planning of our national economy? The answer to that pressing problem depends upon the viewpoint and upon the recognition and proper evaluation of many interrelated factors. It is a complex problem to which no universally accepted solution can yet be given.

Speculations of those who are not intimately of the petroleum industry range from deep pessimism to roseate optimism. This is in part a reflection of the attitudes of a multitude of petroleum geologists, engineers, and executives who are not yet in general agreement on the future of petroleum in this nation. As well stated recently by a leader in the industry, "the facts do not warrant a defeatist attitude of mind but they call for a realistic recognition of the true situation."

What are some of the pertinent facts? Some 26 billion barrels of crude oil have been produced in the United States. We produce and consume three-fifths of the annual production of the world. Petroleum constitutes one-third of the annual production value of all of our diverse mineral resources. Proved reserves are slightly more than 20 billion barrels. They are known to be extractable by present methods from fields that have been sufficiently drilled to afford reliable conservative estimates. Texas, California, and Louisiana contain 80 percent of these proved reserves. Known reserves have doubled in the last fifteen years. Similar reserves in foreign countries amount to more than 33 billion barrels.

During May, 1944, the daily demand for domestic crude petroleum reached a new record of 4,563,800 barrels. That amounts to almost 1.7 billion barrels a year. At the present rate of consumption, our proved reserves would hardly last for the fifteen years that is the common conservative estimate of our national supply. Upon return to peacetime pursuits it is questionable whether the annual demand for petroleum would be significantly decreased, at least as compared with prewar use. It is also open to question whether all of the proved reserves could be extracted during the period of their estimated availability. They might require

twice as long to be fully recovered. It is also of concern that new production in established fields and discoveries of new fields have been lagging for several years behind the rate of consumption. Hence, the pessimists have grounds for their disbelief in the long-continued functioning of petroleum as a major element in our "Oil Age" economy.

Another side of the picture, however, presents itself to many who have the mental and scientific initiative, faith, and courage to disbelieve that the "Oil Age" has either reached its prime or is approaching senescence. Many possibilities for the increase of our petroleum supply are evident. Early drilling was done at the sites of oil seepages or other oil and gas shows. Then came an epoch of random drilling—wildcatting—which is still legitimately in vogue. During the last three decades especially, the function of geology in exploring for petroleum has become increasingly evident. The principles and processes of geology are receiving, and will receive, more extensive and intensive application than even in recent years. Sedimentary rocks in which oil could occur are being studied in great detail in the field and in the laboratory.

Petroleum engineers have also been aggressive in developing better production and refining methods. Their contributions to the recovery of petroleum will undoubtedly be of increasing value in meeting the demands of the future. Secondary recovery processes have been applied to declining wells and will be used increasingly in the future. Although a producing oil well has been drilled to a depth of 15,004 feet, it is probable that even deeper zones of possible oil-bearing strata will be tested. Geophysical exploration has contributed much in recent years to our knowledge of these deeper rocks, even to depths of 30,000 feet. After the famous Spindle Top field had been in production for twenty-five years, an equal amount was produced from deeper strata. Efficiency in the use of petroleum will be greatly increased by automotive and other engineers.

No doubt the ultimately available supplies of petroleum in the United States will be supplemented by supplies from foreign lands. The proved reserves in those coun-

tries may be only a fraction of the petroleum that can be extracted, as much geologic and geophysical exploration remains to be done.

Long before our petroleum supplies have approached the vanishing point, synthetic liquid fuels will become available. It is estimated that our oil shales could furnish 92 billion barrels. It has been estimated by competent engineers that our coal could supply us with both solid and liquid fuels for 1000 years. Synthetic alcohols no doubt will be developed for some of the present uses of petroleum.—ARTHUR BEVAN.

#### FAMILIES AND BAD TEETH

If you are allergic to the dental drill—and dentists' bills—you should have chosen your relatives, especially your immediate ancestors, more carefully. In other words, if you don't like carious molars you can blame gran'ma and gran'pa. This, in substance, is the conclusion of Drs. H. R. Hunt and C. A. Hoppert of the Departments of Zoology and Chemistry, Michigan State College, who made a study of the inheritance of susceptibility and resistance to dental caries in albino rats. The rats were fed on a diet, devised by Hoppert, which permits normal growth, health, and reproductive vigor, but which induces caries in the lower molar teeth. By weight, the diet is 66 per cent coarsely ground polished rice, 30 per cent whole milk powder, 3 per cent alfalfa leaf meal, and 1 per cent NaCl. The diet was instituted at 35 days after birth, and the molars were carefully examined at 14-day intervals. To date 3164 rats have been observed, many as high as 50 times.

The study was started in 1937 when 119 rats were started on the caries-producing diet; of these 116 survived and showed cavities in a time-range of 28–209 days, with an average of 70 days. From these animals, by selection and inbreeding, caries-susceptible and caries-resistant strains have been developed. The close inbreeding reduced heterozygosity by about 19 per cent of the heterozygosity of the preceding generation.

In the caries-susceptible strain the mean for the onset of caries declined from 57 days in the second generation to 22 days in the eleventh generation. In the caries-resistant strain the mean for the second generation

was 116 days, and for the eighth generation 195 days, though in the sixth and seventh generations the means were 248 and 245 days, respectively. In the caries-susceptible strain variability was relatively low. In the caries-resistant strain it was uniformly high, and some of the animals go through life without caries.

It seems to have been demonstrated, almost beyond doubt, that inheritance is a very real factor in susceptibility and resistance to caries in rats. But the genetic picture is still hazy; there is no precise information concerning the gene difference between homozygous susceptible and resistant rats; nor is there any detailed knowledge of the modes of action of these genes or gene-combinations. Research into hetero- and homozygosity, into back-crossing, and into crossing the two strains, still remains to be considered. Still, the principle of hereditary transmission seems to have been firmly established.—W. M. KROGMAN.

#### SOILS TAKE A REST

PLANT growth has been so long accepted by the human race as a matter of course that the continuous functioning of the soil in producing it—if recognized at all—is seldom questioned. Recent concepts of the mechanism of plant nutrition as an exchange between the nutrient ions adsorbed on the surface of the clay particles and the hydrogen or other ions on the plant roots are explaining crop failures and lowered yields in terms of deficiency of available nutritive elements. Such unproductive soils are taking a rest.

The dozen or more chemical elements coming from the soil for plant construction originate in the rock minerals that form the soil. The sand and the silt fractions are rock particles and crystalline minerals not yet decomposed, while the accompanying clay is a seemingly formless product of the rock's chemical change. Clay has little in its molecular structure to contribute to plant nourishment by its own breakdown. But as adsorbers and exchangers of nutrient ions most clays are very effective because of the tremendous surface of their particles. Clay serves as the "jobber" to give its adsorbed nutrients to the plants for hydrogen taken in exchange. It then passes this acidity to

the silt and other minerals to break them down and accept in its place those nutrient elements so obtained from these rock crystals. It is by this mechanism that nutrients are passing from the rock minerals through clay to the plant. Hydrogen as acidity from root growth is passing in the opposite direction. Plants are thus continually exhausting the clay's stock of plant nourishment. It is this exhaustion that produces the phenomenon of resting soils.

Recent plant-soil studies using clay only for plant support showed that a single crop removed the supplies of adsorbed nutrient elements from the clay to an extent ranging from 25 to 85 per cent. Of those elements tested, adsorbed potassium was most rapidly and completely removed. The concentration of acidity or hydrogen on the clay had gone up as the nutrient went down.

These facts point out clearly, then, that after one crop has taken most of the nutrient ions from the clay there could be little for a crop following immediately on the clay. A clay so nearly exhausted then takes a rest from plant production while it restocks itself with nutrient ions from the less active rock particles. It rests from crop production but is active in getting rid of acidity and taking on nutrients by weathering the reserve minerals.

The fall and winter seasons are rest periods of the soil. Low temperatures rule out crop growth but not these beneficial chemical reactions in the soils. Time intervals between crops at seasons other than winter serve similarly. These needs for the soil to take a periodic rest from crop production as indicated by crop failure following immediately after another crop have sometimes been interpreted as injurious or poisonous effects by one crop on another following it too closely. The so-called crop injury has been simply a case of starvation for the soil-borne nutrients. Early plowing in the summer for fall-seeded wheat is a method of hastening recovery from nutrient exhaustion, once explained as moisture accumula-

tion and more recently considered as nitrate accumulation and restocking of the exhausted clay by means of mineral breakdown.

Continued cropping on some experimental plots is demonstrating not only the exhaustion of the clay, but also the exhaustion of the soil's mineral reserves. Where wheat, for example, has been grown annually for 55 years at the Missouri Agricultural Experiment Station, the gradual decline in crop yield for almost 40 years of that time is being followed during the last 15 years by an alternation of crop and noncrop years. This soil is taking a rest each alternate year, demonstrating the fact that not only the clay is exhausted of its nutrient store after a wheat crop in July, but that the mineral reserve has been weathered out so nearly completely that the clay is not sufficiently restocked in October to permit the crop then seeded to go through the winter. Oats as a spring crop, following a winter rest period, are more successful on soil after a preceding summer legume crop of lespedeza than is wheat seeded in October following right behind it. Fallowing at any time is an induced rest period and is an effective agent for a better crop because a better nutrient supply becomes quickly available on the clay and because the water is stored by it.

Intensive cultivation with its depletion of the nutrient stores in our soils is decreasing the grazing season of grasses, is maturing reduced yields of grain crops earlier, and is reducing the yields of seed crops. As we seek to grow more crops by continued cropping and intensive cultivation, the soil takes more rest except as we replenish its nutrient elements by the application of fertilizer. Without such applications the resting clay of the soil restocks itself too slowly.

Our urgent need for increased food production is bringing us to realize that our soils take a rest because we are not giving them sufficient help to save them from exhausting their stock of nutrients required for continuous plant growth.—WM. A. ALBRECHT.

## BOOK REVIEWS

### SPHEROGRAPHICAL NAVIGATION

*Spherographical Navigation.* D. Brouwer, F. Keator, and D. A. McMillen. Illustrated. xxiii + 200 pp. \$5.00. Feb., 1944. Macmillan.

THIS specialized book of navigation is essentially an instruction manual for solving the problems of navigation on the newly created sphere developed by Drury A. McMillen of Brazil.

The idea of a graphical solution of the astronomical triangle on the surface of a sphere is not new, but this method has, heretofore, lacked the required precision for practical ocean navigation. To overcome the difficulties, the inventor has had constructed a precision-made sphere with the necessary supplementary gadgets for drafting. These consist of (1) the spherical compass, with the scribing point and a movable center point with micrometer adjustments; (2) a graduated great circle, by means of which a great circle arc may be drawn on the sphere; and (3) a spherical protractor which furnishes a means of measuring angles formed by the intersection of any two great circles, the divisions extending from  $0^\circ$  to  $180^\circ$  by half degree steps.

Even if the astonishingly high degree of accuracy for this method as claimed by the authors is not generally obtained in practice, the precision of the spherographical system is sufficient for air navigation, where uncertainties of 15 to 20 miles could make a difference in flying time of not more than 4 or 5 minutes.

The McMillen three-dimensional system has the merit of presenting the true geometry of celestial navigation; and it requires no knowledge of the dead reckoning position of the plane since the circles of altitude can be drawn on the sphere with no other information than the chronometer reading of the time of the sights, the sextant altitudes of the stars, and the information contained in the Air Almanac. As with any other method the position obtained must ultimately be plotted on the pilot's map or chart of the region flown.

The authors cover in this small handbook

specific cases and problems of navigation that will be encountered in spherographical solutions. While the authors illustrate the problem of daytime navigation by sun-sights alone, it will be obvious that while waiting for suitable elapses of time between observations of the sun to yield a favorable angle of intersection of two lines of position in azimuth, the accumulated errors incident to carrying forward a line of position during this interval can be considerable, being based on instrument flying alone.

A particularly valuable chapter is that dealing with polar flights, where the spherographical system has the advantage in solving some of the situations encountered in very high latitudes.

The book is in no sense a general treatise on navigation, nor would the authors so claim. It is a small volume of less than 200 pages, well printed, but relatively expensive, as must be the equipment for which the book is specifically written as a manual of instruction.—HARLAN T. STETSON.

### RIDDLES IN MATHEMATICS

*Riddles in Mathematics.* E. P. Northrop. Illustrated. viii + 262 pp. \$3.00. 1944. Van Nostrand.

THIS timely book dexterously builds upon the currently increased interest in mathematics and the ever-present relish for puzzles to impart some solid mathematical principles. The author attempts to do this with a minimum of pain and a maximum of attractiveness to the student, and his efforts must be adjudged fairly successful. Most of the book is avowedly for the reader with only elementary preparation in mathematics.

Opening with a definition and examples of paradoxes, the book goes on to a "few simple brain-teasers." These are all of the order of "catch questions," and close attention to wording will be sufficient to solve them. They involve, however, logical or mathematical thinking, and lead the reader on to more serious problems. Succeeding chapters are on paradoxes in arithmetic, in geometry, algebraic fallacies, geometric fallacies; paradoxes of infinity, of probability,

and of logic. The last chapter ("not for the novice") deals with paradoxes in higher mathematics. Appendices function somewhat as do pages of answers in a mathematical textbook for more formal study; they give brief but clear explanations of the fallacies shown in previous pages. A section of notes and references gives many sources and an idea of historical development of the subject.

The chapter on paradoxes in arithmetic is mainly concerned with an effort to give large numbers a real meaning to the reader and to show the magnitude reached by small numbers with large exponents. The "Tower of Hanoi" with its  $2^n-1$  manipulations is discussed; number theory, including prime numbers and possible systems other than the decimal system, takes some space. Several parlor games are discussed, which are based on familiarity with number systems and algebraic principles.

The chapter on geometrical paradoxes deals with optical illusions, the Fibonacci series and its occurrence in leaf arrangements, extreme-mean ratio, and "logarithmic spirals." The amount of revolution in rollers used to move a slab, properties of curves and cycloids, topology, open and closed surfaces, knots and bordering colors are discussed. Surprising or curious truths bulk large in this section. The later chapter on geometric fallacies deals largely with spurious proofs. They are built up by familiar methods, backed with inaccurate constructions. Tracing out the inconsistencies furnishes good exercise in logic. Use is also made of zero quantities.

The chapter on algebraic fallacies tends to develop familiarity with algebraic manipulations. The fallacies are largely based on cleverly disguised divisions by zero or illogical use of square roots of negative quantities.

"Paradoxes of the infinite" deals with problems of convergent and divergent and oscillating series, and limits of convergent series. Curves, boundaries, and other concepts are related to the idea of infinity. The ideas of one-to-one correspondence and transfinite numbers are developed, and it is brought out that some ordinary numerical standards break down in dealing with infinity.

Some problems in probability are pre-

sented, after stating general principles. Then the changes that come in ideas of probability with an infinite number of possible outcomes are discussed. Necessity of clear definition of probabilities is stressed. Logic is discussed briefly; the paradoxes cited seem to border on the trivial after the heavy diet of preceding chapters.

The last chapter starts off with a paradox in higher mathematics which is a dressed-up version of Achilles and the tortoise. A number of fallacious proofs based on misapplications are shown; their study should be valuable in developing facility in operations in trigonometry and calculus.—F. M. WADLEY.

### ASIA'S LANDS AND PEOPLES

*Asia's Lands and Peoples.* George B. Cressey. Illustrated. vii + 608 pp. \$6.00. 1944. Whittlesey House, McGraw-Hill.

THIS work is monographic in scope and is a product of some one hundred thousand miles of travel in Asia and of two decades of research on part of the author, who, in addition, also has had active co-operation of a considerable number of leading authorities on the subject, making the survey sufficiently definitive as to be almost encyclopedic in character. It presents a comprehensive, readable analysis of the physical and human problems of Asia, especially China, Japan, the entire Soviet Union, and India. The introductory matter includes discussion of the interests of the United States in the Pacific since the days of clipper ships. Then there follows regional treatment beginning with China and Japan. Subdivisions in treatment of China include such subjects as the Chinese landscape, China's physical environment, farming in China, regions of North China, regions of South China, regions of Outer China, and China in the New World. Subdivisions in treatment of Japan comprise such subjects as Japan's natural foundations, the human response in Japan, regions of Old Japan, regions of Outer Japan, and Japan's world position. In like manner those for the Soviet Union consist of such matters as the Soviet realm, environmental factors in the Soviet Union, mineral resources in the Soviet Union, economic developments in the Soviet Union, regions of Soviet Europe, regions of Soviet's Middle

Asia, and regions of Soviet Siberia. Similar discussion of Southwestern Asia treats in detail of the Southwestern realm, Turkey, Syria and Palestine, Arabia, Iraq, Iran and Afghanistan. Like treatment of India comprises India's physical foundations, India's people and their activities, regions of Northern India, regions of Peninsular India, and India's place in the world. The remainder of the book deals with Southeastern Asia under such subjects as the Southeastern realm, Burma, Thailand, Indo-China, Malaya, Netherlands Indies and the Philippine Islands. There also has been included a valuable selection of suggestive readings on the various countries and subjects, limited to more readily accessible literature, though no attempt has been made to list or evaluate the great mass of material from Asiatic sources or that in European languages other than English. The illustrations have been selected with great care from widely separated sources and comprise an outstanding feature of the book. Equal care and consideration have been given to the maps: in order to convey a proper sense of proportion, most of the maps are reproduced on uniform scales and a single azimuthal equal distance projection, so that they may be fitted together if desired. Separate scales are provided for Asia as a whole, for countries and realms, and for vicinity of cities. It is fitting also that mention here be made of the unusual readability of this book. Even those who merely examine it superficially will notice the condensed, compact arrangement of subject matter, and all will approve of the striking manner in which much of its information is arranged so as best to emphasize a point, or bring out clearer a thought, or otherwise make "good reading," as for example: "The key word in Soviet geography is continentality. Within the Union is room for all of the United States, Alaska, Canada and Mexico. From Leningrad to Vladivostok is as far as from San Francisco to London—nine and a half days by the Trans-Siberian Express." It seems exceedingly fortunate that this book should come off the press at this particular time, in view of the prominence of Asiatic countries just now in World War II. Information contained therein doubtless will enable many of its readers to gain clearer

understanding of the physical and human background as well as actual status of that vast drama in various countries, and, to quote the author: "Where controversial issues are involved, these chapters should enable one to bring his prejudices up to date."—J. S. WADE.

#### ATOMIC NIGHTMARES

*Mr Tompkins Explores the Atom.* G. Gamow. Illustrated. x+97 pp. \$2.00. 1944. Macmillan.

THE public is fortunate in having so competent an authority on the structure of matter explain its mysteries in such a whimsically humorous and delightfully stimulating manner. For the greater part of the book no formal exposition is given. What Professor Gamow has very cleverly done is to construct his book in two parts: the first part consisting of three amazing dream-adventures of Mr Tompkins and his wife, Maud, and the second of the four lectures which inspired these dreams.

In the first of these startling dreams, Maud is taken for a tour among the molecules inside her husband's Scotch and soda. Following this crazy experience Mr Tompkins drops off to sleep during a lecture on electrons, only to dream that he himself is a valency electron in a sodium atom. After experiencing all the varied phenomena that electrons undergo, he (the electron!) is finally annihilated in an encounter with a positron. Mr Tompkins awakens. The next exciting event occurs when Mr Tompkins is knocked unconscious in his father-in-law's nuclear physics laboratory by accidental contact with high tension apparatus. This time he dreams that he meets a "woodcarver" of nuclei through whom Professor Gamow presents a very fine popularization on the composition of the nucleus. Mr Tompkins recovers from his shock and swears off ever having anything to do with physics lectures or laboratories. However, the reader, who by now has been acquainted painlessly with the terminology and elementary facts of atomic structure, has no such wish; on the contrary he is anxious to read the four lectures that follow.

These lectures, entitled "Reality of Atoms," "Inside the Atom," "Holes in Nothing," and "The World Inside the

Nucleus," are models of lucid exposition. The reviewer, a former student of Professor Gamow, can testify that the same clarity and plausibility that characterize his classroom lectures have somehow been imbued in the printed word.

This very entertaining and instructive book will be invaluable in bringing the layman up to date in atomic and nuclear physics, a field of ever-increasing importance and of extremely vital future significance.—JACOB POMERANTZ.

### ROBERT BOYLE

*The Life and Works of the Honourable Robert Boyle.* Louis Trenchard More. xii + 313 pp. \$4.50. 1944. Oxford University Press.

ROBERT BOYLE, the "Sceptical Chymist" of the seventeenth century, was one of the great original thinkers of the English heritage. It was his lot, during an age when science was finally breaking away from medievalism, to direct it toward the new empiricism. He became known not so much for his own discoveries in themselves as for the foundations he laid, the philosophical inquiries he set going, and the innovations he made in ideas and methods that others were to pursue. It was an age of great and fearless minds, of whom John Milton, Isaac Newton, and John Locke were probably the greatest. Robert Boyle was of their company.

All this makes Boyle pre-eminently worthy of the excellent biography that Professor More has produced. It is not his science alone, however, that makes Boyle's story so significant, but his consummate humanism. He was a man of his times, when people may have been gullible but they were also inquisitive. He would have been puzzled by the man of science as we know him today, too often preoccupied with some small segment of knowledge and fearful of stepping over the boundaries of his specialty. Boyle was not afraid of getting out of his field, for the whole universe and God and nature were his field, and his inquiring mind recognized no limits. At times it was hard to tell whether he was more theologian or scientist, but to him and his age there was nothing incompatible in being both at the same time. He could write, with equal authority, *Reflections upon the Eating of Oysters, Some Considera-*

*tions Touching the Style of the Holy Scripture, or Spring and Weight of Air.* It was a two-faced age, "half scientific and half magical, half sceptical and half credulous," and if Boyle at times slipped into pure credulity, or held too long to some of the dubious tenets of the alchemy, we must remember that Boyle's age, with respect to the progress of knowledge, must be compared with earlier centuries, not with later ones. The goal of the humanist was to attain as equable a balance as possible between worldliness and otherworldliness, and the degree of such balance achieved by Robert Boyle would have delighted old Erasmus himself. So, while he embraced the mechanistic philosophy, he sought at the same time to reconcile it to his religious orthodoxy and being a humanist chose naturally the *via media* of the Anglican Church as the most reasonable road to salvation.

Professor More gives a scholarly and well-rounded account of Boyle as a theologian, as an alchemist, as a chemist, and as a creative natural philosopher. To do this he had also, of course, to fill in the picture with the rather turbulent political and religious events of seventeenth-century England and with the history of Aristotelian and medieval science. But he has succeeded in subordinating the background to the main picture, and Boyle emerges first as a man and dynamic thinker and second as the one who discovered the law relating pressure and volume of gases at constant temperature. Without minimizing Boyle's epoch-making achievements in chemistry and physics, one may well ask: Which is the more important, actually to discover something new, or to make discovery possible? This life of Boyle is the answer.

It can readily be seen why Professor More (who is also the biographer of Newton) was attracted to writing this biography, for in addition to being a scientist himself he is, as was his brother, the late Paul Elmer More, a distinguished philosopher and humanist-scholar. [An interesting and useful appendix to the book is a reprinting of Paul Elmer More's essay "The Spirit of Anglicanism," germane to Boyle's theology.] As a result he has written sympathetically and with insight of one who advanced human knowledge in many fields.—PAUL H. OEHSER.

## TO SEE OR NOT TO SEE

*Industrial Ophthalmology.* Hedwig S. Kuhn. Illustrated. 294 pp. 1944. \$6.50. The C. V. Mosby Co.

It has been estimated that eye accidents cost the American employer over \$100,000,000 annually, and the injured workers and the communities in which they live an additional \$100,000,000 annually. It has been stated, moreover, that 98 per cent of eye accidents are preventable. In addition to accidents there are certain occupational diseases which exact their toll. Sources of occupational injury to the eyes include: (1) accidents, (2) intense light or heat, (3) toxic substances, (4) inadequate or improper lighting and other abnormal working conditions, and (5) communicable diseases spread by unsanitary work places. Finally, mention must be made of undiscovered and uncorrected defective vision, the magnitude of which is indicated by the results of a number of investigations. In four companies in different sections of the United States, it was found that half or more than half of the workers had defective and uncorrected vision. In one plant three of every four workers had refractive errors needing correction by glasses. The problem of defective vision in terms of production, absenteeism, fatigue, and accident proneness is probably costing worker and employer a sum closely approximating that estimated for eye accidents.

Such in barest outline is the eye problem in industry. What is being done about it? Pertinent in an attempt to answer this question are the results of a preliminary survey recently made with the use of a simple questionnaire mailed to a number of plants. The object of the survey was to determine the status of eye conservation practices. Fifty plants were covered, thirty-two of which employed between five hundred and twenty-five thousand workers each. The results revealed in general a lack of attention to conservation of eyesight as compared with general safety practices. Only a small number of the plants carried out adequate programs for saving eyesight. Job analyses for visual requirements were reported by twelve of the plants. Thirty-five made no tests of the workers' vision or the test made was inadequate. Periodic eye examination of workers was re-

ported by five plants. Prescription lenses were provided for, or required of, the workers in twenty-nine of the fifty plants. Forty plants claimed to supply goggles to workers whom they considered "exposed" while thirty-five fitted the equipment for the comfort of the worker. Eighteen plants issued goggles that had been worn by other workers without a sterilization of the goggles.

Obviously there is urgent need for a comprehensive work on industrial ophthalmology, co-ordinating the essential material on the various problems that confront industry and offering a broad and practical program to meet the needs of industry.

Dr. Kuhn presents her subject under the following subdivisions: visual testing, correction of visual defects for job, visual skills, industrial eye injuries caused by solid bodies, eye protection, and recent developments as related to industrial eye problems. An appendix carries a table of toxic substances and their effects, an all-inclusive eye program for industry, and a standard method of appraising loss of visual efficiency.

The reviewer is deeply impressed, first, by the author's firm conviction that the solution of the industrial eye problem requires the co-operation of other scientists with the ophthalmologist and, second, by the fundamental principle and the fundamental procedure upon which the author chose to base her book. The *principle* is that valid conclusions or recommendations can follow only from the critical assessment of careful and adequate observations. The *procedure* is in essence the "visual job analysis," such an analysis being "the process whereby the component parts of a given job are related directly to the individual visual skills involved in the performance of that job." The adoption of this procedure for fitting worker and job, so far as visual needs are concerned, makes it clear that the old definition of good vision, postulating perfect visual perception, becomes less important, the new definition enunciating that good vision is vision which is adequate for the performance of the tasks presented.

The author shows clearly the various steps leading to fruitful visual job analyses. A job classification list is first secured, this list being supplemented with the precise scope of

each individual job. A trip is made through the plant from machine to machine with someone trained in the mechanical details of machine operations. Pertinent items on what the worker does and on the visual parts of his job are checked on a previously constructed form. These analyses lead to a determination of broad visual admission standards for placement purposes, and to the prescription and fitting of corrected vision glasses or goggles for the job.

The final chapter discusses welding, illumination, epidemic keratoconjunctivitis, general physical health, small plant problems, and the blind in industry.

The book is scholarly, clearly written, and a valuable addition to the growing scientific literature of industrial health. It is replete with suggestions gained from practical experience, of primary importance being those pertaining to the securing of wholehearted co-operation from labor and management. Each of the chapters is followed by a list of pertinent references. The photographs showing various industrial operations were chosen with care. Both the photographs and the typography are kind to the eyes.

The reviewer recommends the book not only to physicians working in industrial ophthalmology but to all plant physicians, nurses, engineers, hygienists, and others charged with the improvement and protection of the health of the worker, and with a better and higher plant production.—W. M. GAFAFER.

#### CALCULUS REFRESHER

*Calculus Refresher for Technical Men.* A. A. Klaf. viii + 431 pp. \$3.00. 1944. Whittlesey House, McGraw-Hill.

In the preface the author states: "The primary purpose of this book . . . is to make available, for ready and rapid use, a "refresher" on the fundamental concepts, methods, and practical applications of simple calculus. . . ." He has succeeded admirably in his purpose. While purists will undoubtedly decry his brevity of theoretical treatment and his empirical viewpoint, technical men who use the book will find that the presentation of the subject is direct and incisive.

The unique feature of the book is the form of presentation—by questions and answers. The questions are well selected, typical of those arising in the everyday application of calculus or helpful in clarifying fundamental concepts. In most cases, appropriate examples follow the answers to the questions, and a list of problems covering subjects treated therein follows each chapter. There is a generous use of the graphical method to illustrate specific points.

The sequence of the presentation is the usual one of differential calculus (Section I) followed by integral calculus (Section II). Also, throughout these sections are placed chapters to "refresh" such related subjects as constants, variables, functions, increments, limits, maxima and minima, types of growth, conditions of logarithmic growth, mean value, center of gravity, and moment of inertia.

Section III is largely devoted to 63 examples of the application of calculus to practical problems. While most of these have an engineering slant (the author is an engineer), yet they range from military construction to bacterial growth. Section III also includes one appendix containing the answers to many of the problems in the first two sections, and a second appendix containing useful mathematical formulas and notations, 201 integration formulas, tables of four place common logarithms, tables of trigonometric functions, and a short table of natural logarithms. There is a nine page index which, although adequate, could profitably be expanded.

The binding of the book is not too sturdy, but the print is clear and legible except for an occasional exponent.

Since it is specifically a calculus text, the book requires a foundation in algebra and trigonometry. Furthermore, although it is well written and devoid of unnecessary details, it cannot by itself "refresh" calculus in ten easy lessons. A serious effort on the part of the user is still necessary.

In addition to serving as a text, this book will also serve well for reference purposes, and it would be a useful addition to the library of a technical man.—S. D. KOONCE.

## COMMENTS AND CRITICISMS

### El Dorado?

In a letter published under "Comments and Criticisms" in the August issue, Colonel E. C. Harwood conveys the idea that the Amazon Valley is a rich, fertile region in which food production can easily be increased. He states: "There is no doubt that modern methods and utilization of land not now producing food (including such vast areas as the valley of the Amazon, now being "pioneered" as our middle west was a century ago . . .) could result in multiplying several times over the present crop and animal products of agriculture."

Food production in the Amazon Valley is being increased and may someday be enlarged to a degree that will no longer necessitate importation of the larger part of its food requirements. But it is far from being the rich, fertile area that many believe it to be. Neither its soil nor its climate is suitable for extensive agricultural development. The Amazon Valley is thickly covered with jungle which yields valuable forest products, such as rubber, chicle, timber, fiber, timbo, nuts, oils, and waxes. However, contrary to the general belief that a soil capable of producing such luxuriant jungle growth must be rich in fertility and suitable for agricultural production, much of the soil in the Amazon Valley is poor. Most of the cleared higher land (land that is not flooded each year) does not produce more than two food crops before its fertility is exhausted. The low lands, which are flooded by the annual rise of the rivers and receive a deposit of silt from the receding waters, are more fertile and can produce food crops year after year. But owing to unfavorable climatic conditions, it is impracticable to make large plantings as the crops must be planted between periods of high water, which brings the harvest during the season of heavy rains. Because of these rains and because the fields would soon be inundated again, the crops must be removed from the fields before they can be cured. With no opportunity to cure the crops in the field, farmers are confronted with the serious problem of drying them artificially so that they can be stored without loss from heating and molding. Even under less humid atmospheric conditions, artificial drying would be an expensive operation, but with the prevailing average relative humidity of 86 per cent during the harvesting season, it is impractical to attempt mechanical drying involving large tonnage with present-known methods and equipment. Small amounts, such as are produced by the average native family on an acre or two of land, can be dried by home methods on platforms with movable roofs or in large heated pans that are commonly used for making farinha.

Due to its poor soil and its unfavorable climate for storage of crops, the Amazon Valley, in my opinion,

is not destined to be developed into an agricultural region. The Amazon Valley with its rich forest products was discovered centuries ago and has been "pioneered" by the English, Germans, North Americans, Portuguese, and Japanese. If this Valley had potential agricultural possibilities, these peoples with their knowledge of agriculture, resourcefulness, and capital would have developed it long ago.—T. T. HAACK.

### The Ragged Edge

I desire to take this opportunity of asking why the cover pages of THE SCIENTIFIC MONTHLY are larger than the inside pages. It seems to me that it would be preferable to have the dimensions of the cover pages the same as the inside pages, in order to avoid tearing the edges of the cover.—PETER HIDNERT.

We shall endeavor to explain why we think an extended cover on the MONTHLY should be used, although the printers had nothing to do with it originally. We suppose it was the editor's idea, possibly for appearance or for other reasons of his own. However, the MONTHLY should have an extended cover at the present time because the sheets or signatures in an untrimmed book vary so much that it would be almost impossible to cut the cover paper to extend over the largest extended sheet of the book, not knowing how much some sheets extend. The reason for the untrimmed book is that some of the subscribers have their copies bound in volumes after the completion of the printing. If the books were trimmed at head, foot and side when printed, the margins when trimmed again after being sewed for the volume would be very small and out of proportion with the fold and bottom margins. This would be especially true of THE SCIENTIFIC MONTHLY at the present time, since the printed page size has been increased. A larger size sheet of paper should be used if it is to be trimmed all around; which cannot be done at the present time because of the paper allotment.—GEORGE M. HOUCK, The Science Press Printing Co.

### Slangage

I wish to take issue with the man who objected, in your Letters Column of the [SCIENTIFIC MONTHLY], to a flippant bit of slang. The fact that the Association is composed of men of science does not compel it to abhor the common American language. Perhaps one reason why men of science are not able to command anything like the attention for their opinions that they deserve is the fact that they carefully adhere to the King's English—whatever that may be—using a "five-dollar" word where a short word of the American idiom would express their meaning far more clearly.—W. B. SHEPPERD.

### Animal Crackers

The article in the July *SCIENTIFIC MONTHLY* by Alfred Gundersen and George T. Hastings, "Interdependence in Plant and Animal Evolution," was most interesting. It seems hardly proper to pick flaws in so stimulating a paper, but it is rather unscientific to speak of the duckbill as "intermediate between birds and mammals" (p. 68), descriptive superficially as that might be. It shows reptilian characters of importance, but the bill on which such stress is laid by this statement is without doubt an independent development, like that of the duckbill dinosaurs. On the same page it is implied that *Archeopteryx* was supposed to feed on fish, whereas the interpretation of the authors that it fed on fruits is more usual, on the other hand the toothed Cretaceous birds probably were fish-eaters. The teeth in these two groups are quite different.

On page 70, the lemurs are said to have some marsupial characteristics; stated in this broad way any mammal might be said to have such, but the special characteristics shared with marsupials do not come readily to mind. On this page the addition of a word would have helped the sentence "Carnivora generally have multiple births, but among [the larger] herbivora. . . ."—JOHN ERIC HILL.

### The Grapevine

I have noticed that in your excellent journal you occasionally give space to articles intended to extend your readers' knowledge of the natural history of our amazing earth. Frequently these have had to do with the science of botany. Therefore, I am led to submit the accompanying piece on one botanical subject on which I have seen virtually nothing in print, in the hope that although it may not be said in any way to advance the science of botany it may nevertheless indicate the author's profound admiration for the indispensable member of the Plant Kingdom referred to. Botany, I have often thought, is perhaps after all the greatest of all the sciences, since man's depen-

dence on plants is so great as to be really breathtaking, as well as dreadfully humiliating. May I add that I was brought up on a grape farm in western New York State and can claim some intimate knowledge of viticulture:

I am a plant, a lowly plant,  
Of leaf and flower and bark and root;  
And though I'm not too elegant,  
I bear such good and gorgeous fruit.

My botany's beyond discredit.

My family? Vitaceae.

Who would not dearly love to edit

My long and luscious history!

I am the faithful old Grapevine,

Whose tendrils pass through stone and brick,  
Along dark hallways serpentine—

No wall too steep or high or thick.

Men tap my strength, nor question source,

Whether it came from here or yon,

And when replete with facts, of course,

I help to pass them on and on.

I little care what people say;

I have no fears; I'm never tearful;

For what I do I ask no pay,

But give them all a gratis earful.

When minds, both lay and scientific,

Get thin and dull, and news is slow,

'Tis then my speed becomes terrific—

Fleeter than wind or radio.

So fast am I that, strange enough,

Often the event pursues the word,

And news of it becomes old stuff

Long, long before it has occurred.

Such sure and quick communication

You'll have to travel far to find . . .

I am a blessing to the nation,

A benefactor of mankind!

—PAUL H. OEHSE